STUDIES OF ENERGY LEVELS AND LIFETIMES IN NEUTRAL AND IONIZED LIGHT ATOMS

Sven Huldt

Lund 1980

STUDIES OF ENERGY LEVELS AND LIFETIMES IN NEUTRAL AND IONIZED LIGHT ATOMS

AKADEMISK AVHANDLING

SOM FÖR AVLÄGGANDE AV FILOSOFIE DOKTORSEXAMEN
VID MATEMATISK-NATURVETENSKAPLIGA FAKULTETEN
VID UNIVERSITETET I LUND KOMMER ATT OFFENTLIGEN
FÖRSVARAS Å FYSISKA INSTITUTIONENS FÖRELÄSNINGS-
SAL B TORSDAGEN DEN 29 MAJ 1980 KL. 10.15

AV

SVEN HULDT
FIL.KAND., VRML

AVHANDLINGEN FÖRSVARAS PÅ ENGELSKA

Contents

1. INTRODUCTION

This thesis consists of 11 papers which deal with energy levels and transition probabilities in atoms. Three different excitation methods have been used:

I: Gas discharge (hollow cathode) (Paper 1)

II: Excitation by an electron beam(Paper 2).

III: Beam-foil excitation(Paper 3 - 11).

The major part deals with experiments using the beam-foil technique. For the measurements performed in Lund the experimental setup, data taking and data analysis systems are particularly emphasized in this summary, since the design and construction of these has been one of the author's main tasks. Included as appendices are short descriptions of the computer-program used for peak-finding and of the on-line data- aquisition system used in the Lund beam-foil measurements.

The papers are:

1: S. Huldt, S-E. Johansson, U. Litzen and J.-F. Wyart:
The Spectrum and Term System of Singly Ionized Ti, to be published.

2: P. Erman and S. Huldt:
Trapping of Non-Resonance Radiation and its Influence on Measured Lifetimes of the 4p and 5p levels in Ar I, Physica Scripta 17, 473 (1978).

3: S.Huldt, L.J.Curtis, B.Denne, L.Engstrom, K.Ishii and I.Martinson:
Observation of Strong Orientation Effects for Levels in Higly Ionized Oxygen, Physics Letters 66A, 103 (1978).

4: K.Ishii, E.Alvarez, R.Hallin, J.Lindskog, A.Marelius, J.Pihl, R.Sjodin, B.Denne, L.Engstrom, S.Huldt and I.Martinson:
Lifetime Measurements for some n=0 Transitions in Cl XIII - Cl XV, Physica Scripta 18, 57 (1978).

5: I.Martinson, L.J.Curtis, S.Huldt, U.Litzen, L.Liljeby, S.Mannervik and B.Jelenkovic:
Lifetimes for Low-lying Levels in Zn I and Zn II, Physica Scripta 19, 17 (1979).

I. INTRODUCTION:

This thesis consists of 11 papers which deal with energy levels and transition probabilities in atoms. Three different excitation methods have been used:

I: Gas discharge (hollow cathode) (Papers 1,2)

II: Excitation by fast electrons (Paper 3)

III: Beam-foil excitation (Papers 3 - 11).

The major part deals with experiments using the beam-foil technique. For the measurements performed in this work the experimental energy, data reduction and data analysis systems are particularly emphasized in this summary. Since the design and construction of these has been one of the author's main tasks. Included in appendices are abstr- descriptions of a computer-program : used for peak-finding ; and of a on-line : data-acquisition : system used in the beam-foil experiments.

The papers are:

I: S. Huldt, H.-G. Johansson, U. Litzén and I.-W. Sporell:
The Rydberg and T-R Systems of Singly Ionized Zn, to be published.

II: I. Martinson and S. Huldt:
Transitions of Ca-Like Ions: Excitation and its Influence on Observed Lifetimes of the 4p and 5p Levels in Ar: I. Physica Scripta 1, 277 (1970).

III: S. Huldt, L.J. Curtis, H. Danzmann, L. Engström, E. Jaeki and I. Martinson:
Observation of Beam-Foil Lifetimes Effects for Levels in Ar: II. Lund Osc. Phys. Laboratory 68A, 103 (1972).

A: E. Lindh, T. Andersson, B. Huldt, S. Liljeqvist, A. Marcelino, J. Ribe, R. Szydlo, B. Wannes, K. Engström, S. Huldt and I. Martinson:
Lifetime Measurements for the Xe II Transitions - In: Ft XIII - Ex XV. Physica Scripta 13, 97 (1976).

B: I. Martinson, L.J. Curtis, S. Huldt, U. Litzén, L. Liljeby, B. Henningsson and B. Jelenkovic:
Lifetimes for Low-Lying Levels in Xe I and Xe II. Physica Scripta 10, 11 (1974).

6: S.Huldt, L.J.Curtis and R.M.Schectman:
A Convenient Doppler-Shift Method for Determining the Velocity of a Fast Ion Beam, Journal de Physique Colloque C1,Suppl. 40, 161 (1979).

7: L.Engström, B.Denne, S.Huldt, J.O.Ekberg, L.J.Curtis, E.Veje and I.Martinson:
Experimental Transistion Probabilities for Intercombination Lines in N IV, O V and F VI, Physica Scripta 20, 88 (1979).

8: L.Engström, C.Jupen, B.Denne, S.Huldt, Weng Tai Meng, P.Kaijser, U.Litzen and I.Martinson:
Lifetimes of the 1s2p $^3P_{0,2}$ Levels in F VIII,J.Phys.B 13, 143 (1980).

9: B.Denne, L.Engström, S.Huldt, J.O.Ekberg, L.J.Curtis, K.Ishii, E.Veje and I.Martinson:
Beam-Foil Studies of Multiply Ionized Oxygen, Physica Scripta 21, 151 (1980).

10: S.Bashkin, G.Astner, S.Mannervik, P.S.Ramanujam, M.Scofield, S.Huldt and I.Martinson:
Lifetimes for Excited Levels in Si I - Si IV, Physica Scripta 21, 820 (1980).

11: B.Denne, S.Huldt, J.Pihl and R.Hallin:
Radiative Lifetimes and Hyperfine Induced Decay of the 1s2p $^3P_{0,2}$ Levels in Al XII, Physica Scripta 22, 45 (1980).

The papers will be summarized in the different sections.

2. CLASSICAL SPECTROSCOPY

(Paper 1: The Spectrum and Term System of Singly Ionized Titanum)

The second spectra of the iron-group elements have been the subject of a series of investigations at our laboratory during the last years. The reason is the great astrophysical importance of these spectra as well as theoretically interesting effects of configuration interaction. This is mainly caused by the competition between 3d and 4s electrons, their binding-energy being

roughly equal for these elements.
The results for Fe II [1] and Sc II [2] have been published as well as a survey over some of the excited configurations in this iso-ionic sequence [3], including data from paper 1.

2.1. Experiment

2.1.1. The Light-source

Much of the success of our recent investigations of the second spectra of the iron-group elements is due to the excellent hollow-cathode light-source developed by Litzen for the study of Fe II [1]. By varying the excitation conditions, and by stigmatic imaging of the interior of the hollow-cathode onto the photographic plate two independent methods for separating ionization stages are available:

If the discharge is pulsed with 80-100 A peak current the second spectrum is enhanced relative to the neutral one, while very few transitions from the third spectrum are seen.

The spatial distribution of light-emitting ionized atoms inside the hollow-cathode differs from that of the neutrals, thus providing another means of separating charge states.

Quick and easy ways to identify lines as belonging to a certain ionization stage are essential in the line-rich spectra of the iron-group elements.

Although transistions from the second spectra usually are weak in a continuous discharge some lines are surprisingly intense. This was first observed by Johansson and Litzen in the work on Fe II [4], and was interpreted as a charge transfer reaction between ionized carrier-gas and neutral iron atoms:

$$R^{+} + M \rightarrow R + M^{+*} + \Delta E ,$$

where R stands for a rare-gas atom from the carrier-gas, M for the cathode metal and ΔE is an energy defect found to be of the order of 0.5 eV at the cross-section maximum. This process selectively populates levels lying roughly E below the ionization energy of the rare gas atoms, and thus explains the observed intensity anomalies.

Apart from being a tool for classifying lines as originating from certain resonantly excited levels this effect could be used to estimate the cross-sections for the processes involved.

Estimates have further indicated the possibility that the process might be sufficiently effective as to produce inverted populations, and thus make laser action possible for several transitions in the iron-group elements, as previously observed for other metal ions [5].

2.1.2. Wavelength determination

Most of the spectrograms in this work were measured manually with an ABBE-comparator. During the course of the investigation, however, the Computerized PDS-Measuring System (ASTOL) for automatic scans of photographic plates at Lund Observatory became available, and this facility was used for a few of the plates. Preliminary results show, that apart from being more than 100 times faster than a manual measurement, the wavelength accuracy for reasonably intense lines is comparable or better in the case of automatic measurements. For the intensity measurements required to explore the above mentioned resonant collisional excitation process the automatic method is probably far superior to the visual estimates.
The programs developed in order to use this facility for measuring the spectrograms are described in appendix A.

2.2. Results

The spectrum of Ti II, which has the ground configuration $3d^2\ 4s$ was analysed in 1927 by Russell [6], who established most of the levels belonging to the low configurations.
Lifetimes for many of the low odd levels have been measured by Roberts et al.[7] and calculated by Kaijser and Linderberg [8].

The present analysis is based on 1240 classified lines, of which about 600 were known before. The low part of the term system is now complete, and about 70 levels of the higher part belonging to the lowest parent-term in Ti III have been established.

3. EXCITATION WITH THE HIGH FREQUENCY DEFLECTION (HFD) TECHNIQUE

Paper 2: P. Erman and S. Huldt:
Trapping of Non-Resonance Radiation and its Influence on Measured Lifetimes of the 4p and 3p levels in Ar I.

3.1. Experiment

The High Frequency Deflection technique is a method for exciting gases by a powerful beam of keV electrons. Lifetimes are determined by a delayed-coincidence technique, and the pulsing of the excitation is

accomplished by sweeping the electron beam across a slit.
The method has been primarily used for molecules, but due to the high intensity and the wide time range available it can compete favourably with most other time-resolved methods even for neutral or a few times ionized atoms.
A comprehensive comparison between the HFD-technique and other time-resolved methods is given in ref [9].

3.2. Results

Paper 2 is a measurement of the lifetimes of the levels of the $3p^5$ 4p and $3p^5$ 5p configurations in Ar I. These levels had been measured previously by various methods, but the results differed by amounts well exceeding the quoted experimental uncertainties. Some of these discrepancies were explained in paper 2 by radiation trapping from the $3p^5$ 4s levels, which can be heavily populated either by resonance radiation trapping, or due to metastability.
As the relevant physical quantities (i.e. the electron excitation and the collisional de-excitation cross-sections, the possibly time-dependent geometry of the interaction region) are hard to estimate, a model is proposed where these are included in a few adjustable parameters. A subsequent fit of this model to the measured pressure-dependent lifetimes shows, that a reliable extrapolation to zero pressure is possible in most cases.

4. EXCITATION BY THE BEAM-FOIL TECHNIQUE

Paper 3 is a measurement of the circular polarization fraction of the light emitted in the O VI n = 6 - 7 transition (3433 A) and the 2p3p ^4D - 2p3d ^4F line in O IV (3737 A) as a function of foil tilt angle.

Paper 4 is an extension to the vacuum UV region of an earlier beam-foil investigation of highly ionized Clorine [10]. Beam energies up to 48 MeV from the Uppsala 6.7 MV EN Tandem accelerator were used, and several $\Delta n=0$ transitions in Li,Be and B-like Cl were observed as well as hydrogenic transitions. Lifetimes were determined for 4 excited levels in Cl XIII- Cl XV.

Paper 5 is a lifetime measurement for some of the low-lying levels in Zn I and Zn II. Transitions in higher members (e.g. Mo) of the Zn I and Cu I iso-electronic sequences have been observed from impurities in Tokamak-plasmas [11], and lifetime measurements which check theoretical calculations are therefore also of plasma-physical interest. The paper

suggests that some of the previously determined lifetimes are too long because of insufficient experimental accuracy.

Paper 6 describes an accurate and simple double mirror method to determine the velocity of a light emitting ion beam by the Doppler-shift of the radiation. This procedure utilizes both the red- and blue-shifted components as well as the unshifted one, in contrast to earlier application of this technique [12,13]. The method was used at The University of Toledo to measure the energy loss in carbon foils. Its accuracy is comparable to other methods (e.g. electrostatic or magnetic analysers), but it has the additional advantage of only using the light emitting particles for the determination of the velocity. These are the relevant ones for time calibration in beam-foil experiments.

Paper 7 is a beam-foil measurement of the transition probability for an intercombination line in Be-like N, O and F. It was done by individual measurement of the lifetimes of the three levels of 2s3p ^3P. The J=1 level lifetime is shortened relative to the J=0,2 ones because of the spin-forbidden branch to the ground level.

Paper 8 is a measurement similar to paper 11 for He-like F (F VIII), and the shortening of the lifetime of the 1s2p $^3P_0$ level due to nuclear spin induced level mixing is observed also in this case, and a value for this effect is obtained.

Paper 9 is a study of O IV - O VII using 2-9 MeV beams from the Lund Pelletron accelerator. Several hydrogenic transitions not observed before were measured as well as a few lifetimes. This paper shows, that wavelength accuracy of better than 0.3 A can be achieved in routine beam-foil measurements by a careful refocussing technique. The wavelengths for hydrogenic transitions were in many cases largely improved compared to earlier beam-foil work.

Paper 10 is a lifetime measurement for levels in Si I - Si IV using good counting statistics. Several of the transitions studied are of astrophysical importance. The results are in many cases considerably shorter than previous measurements.

Paper 11 reports the first observation of the transitions 1s2p $^3S_1$ - 1s2p $^3P_{0,2}$ in He-like Al at 953 A and 900 A. The lifetimes were measured, and theoretical calculations of the hyperfine induced quenching of the J=0 level were verified.

Since the early 1960:s, when Bashkin [14] and Kay [15] demonstrated the use of a foil-excited atomic beam for atomic physics measurements the Beam-Foil method has become the standard method for time resolved studies for multiply ionized atomic systems.

In early beam-foil measurements the influence of systematic errors (e.g. extensive cascading in certain cases) was sometimes overlooked, and the method has in fact been questioned as to its capability to provide reliable lifetimes for resonance transitions in heavy atoms [16]. Therefore, much effort has been devoted to the experimental accuracy in the present investigations. The presence of blends from neighbouring lines, or "cascades" into the level studied from higher levels manifests itself by deviation of the decay from the expected single-exponential behaviour. Good counting statistics are therefore vital in all lifetime work.

The spectral resolution was optimized by the refocussing technique [17] for compensating for the wavelength spread in the observation cone caused by the doppler effect.

Measurements have also generally been made at different energies, as to reveal the presence of blends from other charge states.

In most cases the cascades have been accounted for by fitting of a sum of exponentials to the experimental data. In those cases, where the lifetime of the cascade is close to that of the transition studied, or when the cascade decay itself deviates strongly from a single-exponential behaviour, as seen for many of the YRAST-transitions, cascade influences have been accounted for by direct measurement of the most important contributions, and subsequent analysis by e.g. the ANDC [18] method.

The inherent weakness of the beam-foil source sometimes makes the application of these techniques tedious, but at least for the UV-region, where essentially noise-free detectors exist, and for MeV beams of moderately heavy elements, where foil degradation is not a serious problem, the desired statistical accuracy can generally be achieved by increasing the time of measurement.

Finally, the recent development of multichannel optical photon detectors may turn beam-foil spectroscopy into a true multi-channel method, thus increasing the power of the method by orders of magnitude. Work in this direction has already been initiated at the Lund laboratory.

4.1. Experiment

This section describes the experimental setup at the University of Lund. The reader is referred to ref[19] and [20] for similar descriptions of the facilities at AFI, Stockholm (used in paper 5,10) and at Tandem Accelerator Laboratory, Uppsala (paper 4,11).

4.1.1. The accelerator

The NEC 3 MV UDH Pelletron tandem accelerator was installed in the Physics Department of the University of Lund during 1975, and has been used for beam-foil work since 1976. The ion source is a duoplasmatron which restricts the available elements to gases which can form negative ions. A lithium-vapor charge-exchange cell has been mounted during 1979-1980, but has so far (April 1980) only been used for test experiments with He, B, Al and P.
After aceleration and stripping the beam is analysed by a magnet, which also acts as a switching magnet between the five different beam-lines.

4.1.2. Target chamber

The target chamber is made of aluminum, sealed with O-rings. A foil-wheel is mounted on a carriage, which can be positioned by a precision screw connected to a stepping motor via a high-vacuum feed-through. The pitch of the screw is 6 mm, giving a minimum displacement of 1/16 mm with the present stepping motor (96 steps/turn). The total travelling distance between the end-point switches is 232 mm.
The beam can be viewed through three ports, one of which has been adapted to a vacuum spectrometer as described below.

4.1.3. Spectrometers

Three different spectrometers have been used:

A .35 m McPherson EUE-700 monochromator (Paper 3)

A 1 m McPherson Model 2051 grating monochromator (Paper 9,7)

A 1 m Minuteman 310 NIV normal incidence vacuum monochromator (Paper 8).

The original entrance slit assembly of the Minuteman normal incidence monochromator has been replaced by the specially designed one shown schematically in fig 1. By this arrangement the slit can be moved arbitrarily close to the beam in order to optimize the spatial (time) resolution in

lifetime-measurements. The other two spectrometers were optically coupled to the chamber by lenses.

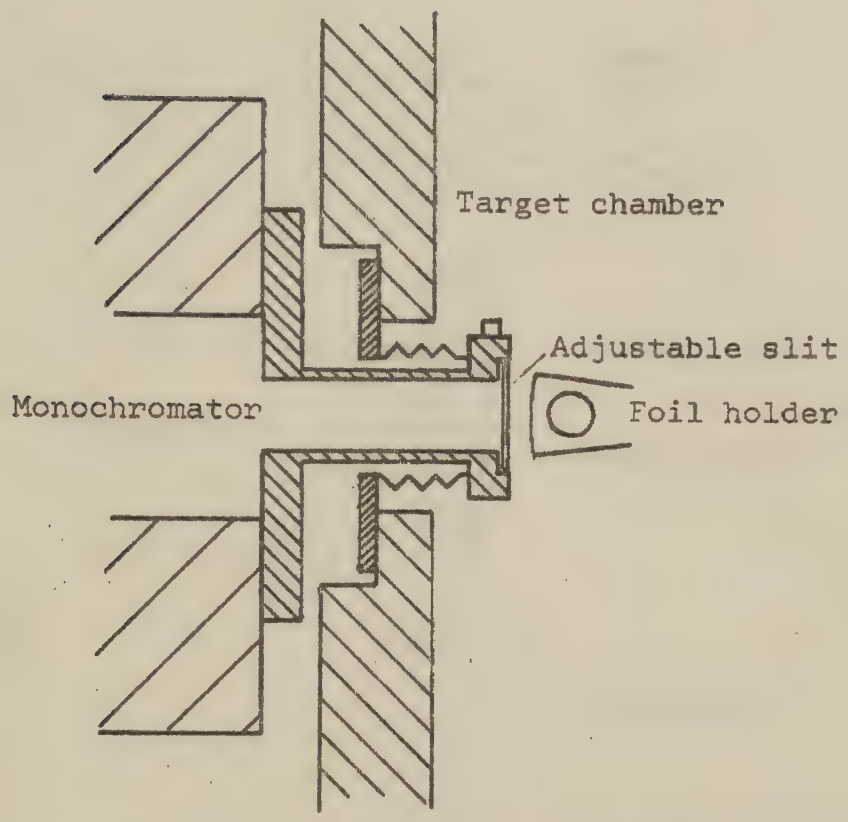

fig 1: The slit assembly

The .35 m McPherson spectrometer could be rotated around an axis perpendicular to the plane of the entrance slit. This allowed the slit to be parallell to the foil exit-surface in tilted-foil studies.

The detectors used in this work are:

1: A 9789 QB Photomultiplier, cooled by solid CO_2 or N_2 for wavelengths greater than 2000 A.

2: An EMR 541F Photomultiplier (1050 A - 2500 A).

3: A Bendix channeltron electron multiplier (300 A - 1100 A).

All the detectors were operated in the pulse counting mode. The noise counts from detector 1 was about 1/s, and less than 0.1/sec for the other two. The pulses from the detectors were fed into a modified ORTEC 113 preamplifier and further amplified and discriminated by standard NIM-electronics.

For the polarization measurements a system similar to that of Berry et al.[21] was constructed. The system is described in ref[22].

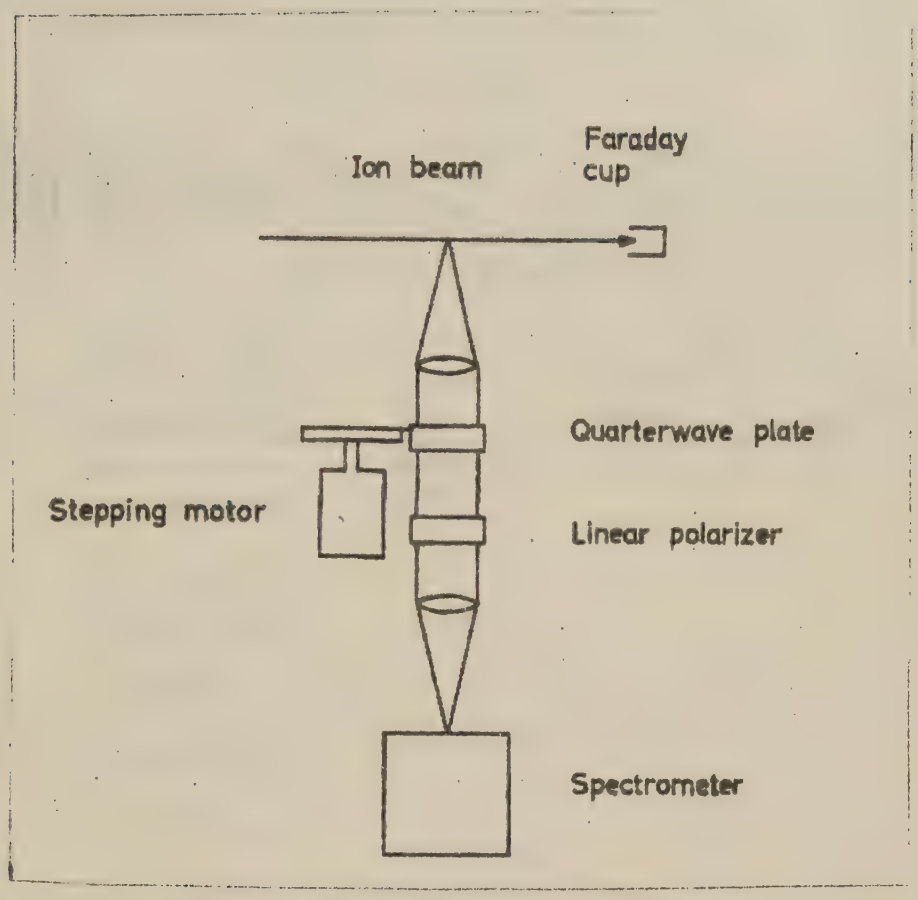

Fig 2 The polarization analysing system.

The quarter-wave plate is rotated relative to the fixed linear polarizer, which allows simultaneous measurement of linear and circular polarization. With this method, no correction for instrumental polarization after the analysing system is necessary.

4.1.4. Data control and aquisition system

The measurements are fully automated by means of a minicomputer based system designed and built at the institution. The system consists of a computer with various peripheral devices, including a graphical terminal, and a experiment control unit, which handles 1-8 subordinate units. Each of these may have up to 8 sub-units connected which are specially designed for each task. The general lay-out is shown in fig 3.

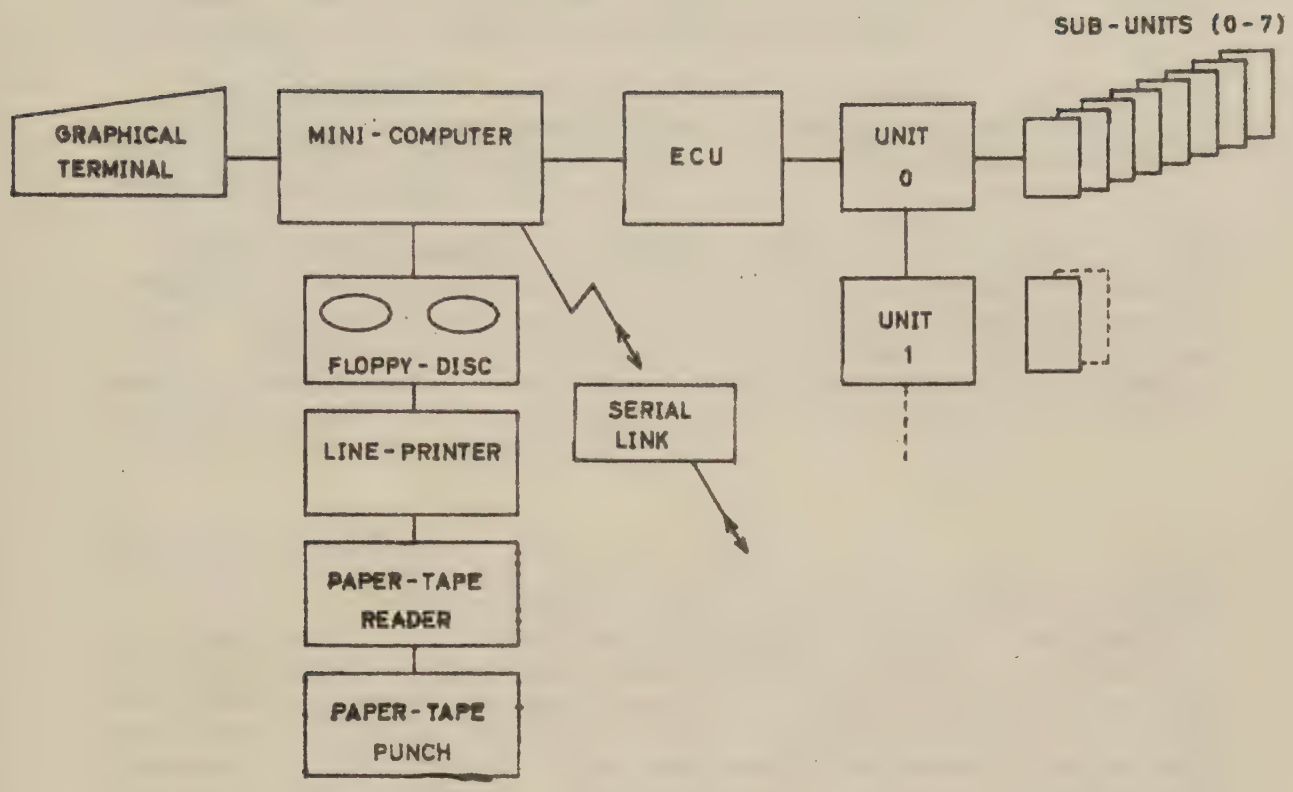

Fig 3 The data aquisition system.

4.1.4.1. Hardware

The following requirements were emphasized in the hard-ware design:

- The computer should be as inexpensive as possible, and yet provide sufficent computational power for adequate data-analysis.

- The experiment control unit (ECU) should be as computer-independent as possible.

- No hardware limitations within reasonable limits as to the type or number of connected devices should be built into the system.

- No restrictions as to the length or character of the I/O-sequences between the computer and the actual devices should be imposed by the hardware.

- The device-dependent hardware should be logically placed as far as possible from the computer.

The minicomputer chosen is a Computer Automation ALPHA-LSI 2/20 with 64 kB core memory. The experiment control programs are run under the standard operating system, which supports FORTRAN IV as well as various I/O-devices in a device-independent fashion.

As primary data-storage a PERTEC FD 511 dual floppy-disc system was chosen. Provisions for connecting the ALPHA-LSI computer to other computers by a serial link were included from the start.

The experiment control unit is connected to the computer by a standard 16-bit I/O-interface, and is cabable of generating interrupts on two levels, one of which presently is reserved for a preset scaler. The use and designation of the 32 data-lines and the 9 control-lines is included in appendix B together with a brief functional description.

4.1.4.2. Software

The aim of the software design was to create a system that allows reconfiguration without detailed knowledge of the hardware, and without ASSEMBLER-language programming. This was achieved at the expense of an efficient interrupt handling, but at the interrupt rates expected (> 1 sec between interrupts) this was not considered important. While the hardware was designed to be as general as posiible the software was optimized for typical beam-foil studies.

For each type of sub-unit a driver routine was written, callable from a high level language. The necessary information is contained in parameters, supplied at each call.

An interrupt from the ECU activates a simple handler which does the necessary resetting etc. of the ECU and then transfers control to a user-supplied high level language program, looking exactly like a ordinary FORTRAN subroutine. Normally, this routine stores five scaler-readings on a floppy-disc in a list-mode fashion and plots the data on a graphical terminal.

This scheme has proven to be adequate for our beam-foil measurements, and no ASSEMBLER-programming has been done after the initial test and debugging of the routines in 1977. The FORTRAN parts of the system have been rewritten several times, however.

The details about the running experiment are as far as possible contained in a parameter block, which is initialized by a stand-alone program prior to the start of the measurement. This parameter block, together with a copy of the data-buffer in the computer memory, is dumped onto the floppy discs at regular intervals, thus guaranteeing restartability and minimum data-loss in case of malfunctions.

4.1.5. Data analysis

4.1.5.1. Spectra

The wavelength spectra were generally analysed by a version of the program PEAKF, described in appendix A. Due to the "sine-bar" drives of all the used monochromators the relations between stepping-motor position and wavelength were almost perfectly linear within our accuracy, the terms of higher degree never contributing to more than 0.3 A of the total wavelength in the polynomials used. Periodic deviations corresponding to errors in the gears have not been found.

4.1.5.2. Decay curves

The experimental decay-curves were analysed by either the ANDC-method [18] or by non-linear least squares curve-fitting. The latter was accomplished by the use of two programs: DISCRETE [29] or DECFIT.

Both programs fit a sum of exponentials to the experimental data. DISCRETE chooses sets of starting values completely automatically, thus avoiding any possible errors from biased initial estimates. A linear hypothesis test corrected for nonlinearity is then used for deciding which set of start values (including the number of exponentials in the sum) is the "best", "second best" and so on. The program is thoroughly described in ref [29].

An additional program DECFIT was written for two main reasons:

1: To take advantage of of a human operator supervising the fitting, and to allow change or fixing of a parameter at any time during the process.

2: To obtain the appropriate weighting for beam-foil data. The usual approach is to correct for beam-independent (detector) noise by subtracting the time spent in each channel multiplied by an accurately determined factor from the result prior to the fitting. Each datum is a sum of samples from this constant distribution and from the signal, both of which obey poisson-statistics. As the sum again is Poisson distributed the statistical uncertainty in each point should be determined from the uncorrected value. DECFIT keeps the original data set througout the fitting process in order to achieve this. A further advantage is that the beam-independent background (as well as a beam-dependent) can be varied during the fitting, thus providing a check of the measurement of the detector noise.

The importance of a proper treatment of the background in lifetime measurements has been pointed out in ref [23].

4.2. Results

4.2.1. Atomic Energy Levels

In spite of its weakness and limited wavelength resolution the beam-foil light-source has been used for energy-level determinations in certain cases:

- For very highly ionized systems, the beam-foil source is one of the few ones available in the laboratory.
- Multiply excited states are known to be strongly populated in the foil-excited beams as compared to many other sources.
- Transitions between high-lying hydrogen-like levels are comparatively strong, and the low density of atoms in the beam prevents these levels from being disturbed by Stark-effect.

Measurements of energy-levels in highly-ionized few-electron atoms can provide important tests of relativistic and quantum electrodynamic (QED) effects. As these scale as powers of $(\alpha Z)^2$, while electron correlation effects can be expressed as an expansion in 1/Z the effects are more easily verified the higher the nuclear charge.

Paper 11 reports the first observation of the 1s2s-1s2p transitions in He-like Al. The production of this ion was at the time for the experiment at the limit of the capability of the Uppsala 6.7 MV tandem accelerator, and the low beam-current and limited measurement time available made an accurate wavelength determination impossible. This would otherwise have provided interesting information about QED-effects for 02Q electron ions [24]. The main effort was therefore placed on a lifetime-measurement in order to verify the influence of a nuclear-spin induced transitions.

For high-lying, non-penetrating hydrogenic orbits the energy can be accurately desribed by the polarization formula:

$$T(n,l,Z) = T_h(n,l,Z) + \Delta_{pol}(n,l,Z) ,$$

where $T(n,l,Z)$ is the term value, $T_h(n,l,Z)$ the hydrogenic term value from Dirac-theory and Δ_{pol} the polarization energy, which can be expressed as:

$$\Delta_{pol}(n,l,Z) = A(Z)\ P(n,l)(1+k(Z)q(n,l)) ,$$

where the functions P(n,l) and Q(n,l) have simple analytical forms [25] and A(Z) and k(z) involve the dipole and quadrupole polarizabilities of the electron core.
In the case of He-like ions the known polarizability of the one-electron core can be used to get an accurate determination of the ionization limit. A subsequent comparison with the accurate relativistic calculation available for this sequence [26,27] can then be used for determining the QED-corrections to the $1s^2$ ground state energy.
Paper 9 shows, that the polarization formula provides excellent estimates of the hydrogenic part of the O IV - O VII term-systems. The value obtained for the ionization potential of O VII, although slightly more accurate than previous ones, does not allow test of higher order QED-contributions to the ground-state energy for this ion.
Work is in progress to improve the accuracy by additional measurements in the vacuum UV.

4.2.2. Atomic Transition Probabilities

The possibility of measuring the intensity of a transition as a function of the time elapsed since the excitation is probably the most important feature of the beam-foil light-source. A large fraction of all measurements of lifetimes of excited levels in atoms have been performed with this method.

The lifetime τ of an excited level is defined as the time required for decay of 1/e, i.e. 37% of the initial population. This quantity is related to the more fundamantal probability for a spontaneous decay from the level i to the level f, A(i,f) by the relation:

$$1/\tau = \Sigma A(i,f) ,$$

where the summation is over all final states. In those cases where several A(i,f):s contribute substantially their relative magnitude has to be known for an absolute determination. For neutral or a few times ionized atoms emission experiments can provide relative transition probabilities, and these can then be put on an absolute scale by a beam-foil lifetime measurement.

Paper 7,8 and 11 all deal with determinations of transition probabilities, A_2, which for some reason are not accessible by a direct mesurement. They contribute to the lifetime together with a bigger component, A_1:

$$1/\tau = A_1 + A_2 ,$$

where eventually A_1 may be a sum of several contributions.
As the A_2 in these cases is the difference between two numbers roughly equal in magnitude, experimental accuracy is essential. In the present cases the A_1 could

be calculated or estimated from experiments, and a determination of t thus provides information on A_2.
The A_2 may arise from higher order processes or forbidden decay modes. Experimental measurements of these effects are usually of considerable value to atomic theory.

The hyperfine-induced quenching of the 1s2p ^3P level in He-like ions has been calculated by Mohr [27) for odd Z in the range Z=9 to 29. In order to verify the calculation measurements have been performed on Al and F. The effect arises from mixing of the F = I levels of the 1s2p ^3P J=0 and J=1 levels. The J=1 level has a very short lifetime compared to the other two in this triplett due to the strong (spinforbidden) transition to the ground state, which scales as Z 10 and completely dominates over the allowed E1 1s2s ^3S - 1s2p ^3P transition already for these elements. The mixing of the levels tends to decrease the difference in lifetimes, which can be seen as a shortening of the lifetime of the J=1 level as compared to a calculated value not including the hyper-fine interaction, or to the (scaled) J=2 lifetime. The J=2 level is much less affected due to the larger energy separation to the J=1 level. The effect has been qualitatively been verified for the 1s2p $^3P_2$ level in V XXII, but the interpretation of the results is favourable in our cases, as the main effect is expected from the single hyper-fine level resulting from the coupling of the nuclear angular momentum to a J=0 level.
Paper 8 and 11 thus provide the first quantitative experimental data.

In the Be I sequence the $2s^2$ ^1S - 2s2p ^3P intercombination transition probability has been measured for Fe XXIII [28]. However, since the 2p ^1P and 2p ^3P levels are well separated the mixing is not very strong which results in a low $2s^2$ ^1S - 2s2p ^3P transition probability, unless extremely high Z systems are investigated.
The situation is quite different for the intercombination line $2s^2$ ^1S - 2s3p ^3P , which, as shown in paper 7, can be studied already in He-like N, O and F. Since this transition was outside the range of the available experimental equipment the transition probability was determined by its influence on the 1s3s ^3S - 1s3p $^3P_1$ relative to the 1s3s ^3S - 1s3p $^3P_{0,2}$ transitions.
Elborate relativistic calculations of this transition probability by Hibbert [30] shows excellent agreement, well within the perhaps somewhat conservative error bars of paper 7.

For transitions between low-lying states in neutral or a few times ionized medium-light atoms the main theoretical uncertainty is due to electron-correlation effects. Beam-foil determinations of lifetimes for the lowest excited states are often difficult for these elements due to in-shell cascades. Good experimental accuracy was therefore important in the measurements on

Si and Zn presented in paper 5 and 10. This problem is most severe for the Zn I and Zn II resonance transitions, and it has been pointed out [16] that multi-exponential curve-fitting in these cases easily can yield erroneous results.
The results in paper 5 show that careful beam-foil experiments agree with theory, while standard curve-fitting applied on measurements with deliberately poorer statistics in fact reproduces some of the earlier too long lifetimes.

4.2.3. The Excitation Mechanism

The interaction between a thin foil and a transversing fast ion beam is often decribed as being comprised of two major processes:

(1): multiple collisions with the bulk atoms inside the foil, and

(2): exit surface effects. These can either be electron- pickup processes or be caused by some macroscopic field present at the foil surface.

Evidence supporting the first description is K-shell vacancy production and the observed high populations of multiply excited states in foil-excited beams as compared to other light sources. The second description has to be used to explain tilted-foil experiments, which unambigously show an effect of the macroscopic surface on the final excited state of the outgoing ion.

The high n-states often observed in beam-foil sources are generally believed to be the result of a pick-up processes at or close to the exit surface, as the dimension of these ions are big compared to the inter-atom distances inside the foil.

There exists at present no complete model for the interaction. As a first step in providing the experimental data needed for such a theory, the resultant state of ions excited by a foil has been determined in various experiments, e.g. ref[31].

A measurement of the polarization of the emitted light from the 3433 A transition in O VI (6f,g,h-7g,h,i) and the O IV 3737 A line (2p3p ^{4}D - 2p3d ^{4}F) is reported in paper 3 using tilted foils. A substantial circular polarization fraction was found for large tilt-angles (30% and 15% for the two transitions), which tended to decrease with energy. Subsequent measurements [32] with the automated system described earlier confirmed this result and decreased the uncertainty considerably.

Recently the interest has also been directed towards the unbound electrons known to be present [33,34], as these may be important for the process.

Acknowledgements

I would like to express my sincere gratitude to my supervisor Professor Indrek Martinson who introduced me to the field of beam-foil spectroscopy, and ever since has shown great interest in all my work.

I am also very much indebted to Docent Ulf Litzen who has been my teacher in classical spectroscopy for his help and support.

Discussions with Professor Bengt Edlen, Docent Jan-Olof Ekberg and Dr. Sveneric Johansson are gratefully acknowledged.

For his skilful building of the electronics I would like to sincerely thank engineer Arne Svensson.

Mrs Sonja Mickelsson and Miss Monica Andersson have mesured plates, made drawings and assisted in the duplication of this thesis, for which I am most grateful.

I would also like to sincerely thank all my coauthors and collegues at the department for their continous support and encouragement.

At last I would like to thank LUCAS-BERTIL for his patient editing and typing of this manuscript.

5. References

1: Johansson, S. and Litzen, U., Physica Scripta 10 ,3 (1974)
2: Johansson, S. and Litzen, U., Physica Scripta 22, 49 (1980).
3: Johansson, S., Litzen, U., Sinzelle, J. and Wyart, J.-F., Physica Scripta 21, 1 (1980).
4: Johansson, S. and Litzen, U., J. Phys. B 11 (1978)1703.
5: Bridges, W.B., Methods of Experimental Physics 15A, (Academic Press, New York 1979) p.120.
6: Russel, H.N., Astroph. J. 66, 283 (1927).
7: Roberts, J.R., Andersen, T. and Sorensen, G., Astrophys. J. 181, 576 (1973).
8: Kaijser, P. and Linderberg, J., J. Phys. B 6, 1975 (1973).
7: Erman, P., Physica Scripta 11, 2 (1975).
10: Hallin, R., Lindskog, J., Marelius, A., Pihl, J. and Sjodin, R., Physica Scripta 8, 209 (1973).
11: Hinnov, E., Phys. Rev. A14, 1533 (1976).
12: Sorensen, G., in Beam-Foil Spectroscopy (I.A.Sellin and D.J.Pegg, eds., Plenum, New York 1976) p. 165.
13: Pinnington, E.H., Nucl. Instr. Meth. 90, 93 (1970).
14: Bashkin, S., Nucl. Inst. Meth. 28,88 (1964).
15: Kay, L., Phys. Lett. 5, 36 (1963).
16: Younger, S.M. and Wiese, W.L., Phys. Rev. A17, 1944 (1978).
17: Stoner, J.O. and Leavitt, J.A., Appl. Phys. Lett. 18, 477 (1973).
18: Curtis, L.J., Berry, H.G. and Bromander, J., Phys. Letters 34A, 169 (1971).
19: Liljeby, L., Thesis (Stockholm 1979).
20: Hallin, R., Lindskog, J., Marelius, A., Pihl, J. and Sjodin,R., Physica Scripta 8, 209 (1973), and Pihl, J., Thesis (University of Uppsala 1976).
21: Berry, H.G., Gabrielse, G. and Livingstone, A.E., Appl. Opt. 16, 3200 (1977).
22: Engstrom, L., Atomic Spectroscopy, University of Lund, Annual Report 1978.
23: Remy, F. and Dumont, M.N., J. Quant. Spectrosc. Radiat. Transfer 20, 217 (1978).
24: Edlen, B. and Lofstrand, B., J. Phys. B3, 1380 (1970).
25: Edlen, B., Handbuch der Physik 27, S. Flugge, ed., Springer Verlag, Berlin 1964, p. 80.
26: Lin, C.D., Johnson, W.R. and Dalgarno, A., Phys. Rev. A15, 154 (1977).
27: Mohr, P.J., Beam-Foil Spectroscopy .(I.A. Sellin and D.J. Pegg, eds., Plenum, New York 1976) p. 97.
28: Dietrich,D.D., Leavitt,J.A. Bashkin, S., Conway, J.G., Gould, H.,MacDonald, D., Marrus, R., Johnson, B.M. and Pegg, D.J., Phys. Rev. A18,208 (1978).

29: Provencher, S.W., J. Chem. Phys. 64, 2772 (1976).
30: Hibbert, A., J. Phys. B 12, L661 (1979).
31: Schectman, R.M., Curtis, L.J. and Berry, H.G., Journal de Physique, Colloque C1, Suppl. 40, 289 (1979).
32: Atomic Spectroscopy, Univ. of Lund, Annual Report 1978.
33: Sellin, I.A., et. al., private communication.
34: Berry, H.G., private communication.

APPENDIX A

COMPUTER PROGRAMS FOR ASTOL-MEASUREMENTS OF SPECTROGRAPHIC PLATES

Name	Purpose	Computer	Language	Input/Output
	PDS-control	HP 2112	HP BASIC	PDS-transmission readings/ Magnetic tape
PEAKF	Peak-finding	LUCAS/LDC	FORTRAN	Magnetic tape Peak list
POLYF	Wavelength determination	LUCAS/LDC	FORTRAN	Peak list, reference wavelengths/ Wavelength list

Computer programs for ASTOL-measurements

The ASTOL PDS-photodensitometer measures the transmission in equidistant points along a selected line on the photographic plate.
The measurement is handled by an INTERDATA 7/16 computer which in turn is controlled by a BASIC-program running on a HP 2112. By commands to this BASIC-program the distance between the samples, the measuring speed, the total number of samples etc can be varied.
The results are dumped on magnetic tape and further processed at LDC or the LUCAS-computing center:
The Program PEAKF determines the positions and intensities of the peaks according to a modified version of the method decribed in ref [1], and outputs a peak list. As an option the transmission recordings can be plotted on a graphical terminal together with marks indicating the peak positions.
The list and a set of reference lines is then fed into the program POLYF, which determins the wavelengths by standard least-squares fit to a polynomial.

Program PEAKF

Purpose: To find the positions and intensities of spectral lines from an array of equidistante intensity-readings.

Programming language: FORTRAN 77.

Method:

The peak-finding algorithm is similar tothe one used in ref 1. Its main advantages are speed and simplicity. As each peak in our cases consists of a rather small number of data-points, a more sophisticated peak-fitting is not beleived to significantly improve the result.
After optional smoothing of the intensity-readings the first and second differences are calculated. For recordings using linear detectors the logarithms of the intensities are used.
A region with negative second differences is preliminarly considered to contain a peak. Three criteria are used to decide whether the peak is real or not:

1: The intensities in the zero-crossing points of the second difference and in the middle of the region are detemined. If the difference between the latter and the average of the former is less than a certain number the peak is rejected.

2: If the number of (smoothed) points in the region is less than a certain number the peak is rejekted.

3: If the number of (smoothed) point in the region is greater than a (large) fixed number the peak is considered to be due to variations in the background, and is rejected.

If the peak meets all three criteria it is considered real by the program, and the quotient of the first-differences at the zero-crossings of the second differences is calculated (FDQ). The position of the peak is then determined by a method choosen by the program :

If FDQ is reasonably close to the value for a symmetric peak (-1) the position is determined by a fit of a straight line to the first differences in the region.

Otherwise, the peak is considered distorted and the middle of the region is taken as the peak position.

The intensity of the peak is taken as the average of (smoothed) points centered around the peak position. For ASTOL-measured spectrograms the intensity scale is determined by the adjustment of the PDS-machine. If the standard procedure [2] is followed then 0 corresponds to total and 1000 to zero transmission. (To avoid the occurrence of negative intensities the value for "clear" plate is usually choosen to be about 40.)

Input:

The program is interactive and requests input from an operator at a terminal.

Output:

The result is written on the selected device as follows:

Line 1-10: Heading and general information.

Line 11-(10+number of found peaks):
LINE,PEAK,POS,INT,SKEW,SLOPE,NPOINTS

FORTRAN FORMAT: (2I6,1X,F10.1,F6.0,F6.2,F3.1,I4)
LINE: Scan line number (see ref 2 for explanaition)
PEAK: Number of peak in current scan line.
POS: Position in um.
INT: Intensity.
SKEW: Skewness indicator (=-FDQ).
SLOPE: The slope of the straight line fitted to the first differences.
NPOINTS: The number of (smoothed) points in the region.

References:

1: Hoekstra, R., Appl. Opt. 6, 5 (1967).

2: Guide for the use of the computerized PDS-measuring system (ASTOL) at Lund Observatory, Sweden (1979).

APPENDIX B

Experiment Control Unit (ECU) interfacing

Listed below are the designation and function of the 41 signals needed to use the ECU. All signals are defined relative to the I/O-interface in the computor (i.e. "out" means from the computor to the ECU), and buffers refer to I/O-buffers in this interface.
All levels, rise(fall)time and length of pulses should be compatible with standard TTL circuitry.

Direction	Designation	Function
	Data lines:	
in	IB0-IB15	Input data lines
out	OB0-OB15	Output data lines
	Control lines:	
in	RNT1	Interrupt request #1
in	RNT2	Interrupt request #2
out	EX	External control, next output is an address
in	ES	External sense (not used)
out	OBF	Output buffer full
in	IBF	Input buffer full
in	OBRS	Output buffer ready strobe, causes OBF to go low
out	STB	Output data strobe
in	EST	Input data strobe

Functional description

A typical I/O-sequence in terms of the above defined signals schematically looks as follows:

1: Output a pulse on EX to tell the ECU that the next data word on OB0-OB15 is to be interpreted as an address.

2: Output a 16-bit word, where the 7 low bits are significant and are interpreted as foillows:

BIT 0-2: Unit Selector adress

bIT 3-5: Sub-unit address

BIT 7: Master Clear

3: Optianally read the previous address. (Tbis option is selectable by a front-panel switch.)

4: Execute the sub-unit dependant I/O-sequence.

The spectrum and term system of singly ionized Titanium, Ti II.

Sven Huldt, Sveneric Johansson and Ulf Litzén

Physics Department, University of Lund, Sölvegatan 14, S-223 62 Lund, Sweden.

and

Jean-Francois Wyart

Laboratoire Aimé Cotton, CNRS II, F-91405 Orsay, France.

Abstract

The Ti II spectrum has been recorded in the region 1100 - 11000 A. 1240 lines have been classified as transitions between 204 levels of the configurations $(3d + 4s)^3$, $3d^2nl$ and 3d4s4p. Parametric studies including configuration interaction have been made for a number of configurations.

1. Introduction

Russell's analysis of Ti II from 1927 [1] was based on observations of the spectrum in the region 1906 - 6717 Å. The term system, included in AEL [2] and a compilation by Corliss and Sugar [3], comprised 116 levels which were derived from 529 classified lines. The lower part of the term system was well known from Russell's work, but it was obvious that an extension of the analysis to higher configurations was needed for the identification of essential features of the spectrum. Also in the fundamental configurations $(3d + 4s)^3$ additions were needed, as $3d^2(^1S)4s\ ^2S$ seriously disagreed with theoretical predictions, and the upper ^2D term of $3d^3$ was missing. Moreover, an extended analysis was essential for an iosionic study of the singly ionized ion group elements [4].

In the present work the titanium spectrum emitted from a pulsed hollow cathode discharge has been recorded in the region 1100 - 11000 A. The experimental procedure has been described in detail in recent articles on Fe II [5] and Sc II [6].

2. The observations

Table I contains 785 classified Ti II lines above 2500 A observed in this work. 464 lines were previously known in this region. The intensity figures in the first column of the table are based on visual estimates of the photographic blackening without corrections for the varying spectral response. The intensities are thus comparable only over limited wavelength regions. The classifications are given in the last columns, one for the combining configurations and one for the levels. In the configuration column nl stands for $3d^2nl$, s2 for $3d4s^2$ and sp for 3d4s4p. In the level column the lower case letters are those traditionally used to distinguish terms of the same kind in complex spectra, as given in AEL [2]. Terms established in this work have not been given such designations, except the upper ^2D term of $3d^3$, where the designation d ^2D is introduced. Multiplicities and J-quantum numbers are placed on the line and not as super- or subscripts.

Table II contains 455 classified lines that have been observed below 2500 A, where some 125 lines were previously known (Russell [1], Movahed-Ardabili [7]). The wavelengths have been calculated from the energy levels of Tables III and IV. The observed intensities are shown in the first column.

3. The term system

Figure 1 shows a survey diagram of the known Ti II configurations. Level values of all the presently known levels are given in Tables III and IV.

3.1 The configurations $(3d + 4s)^3$.

The fundamental configuration complex of Ti II, $(3d + 4s)^3$, is now completely known. The previous value of $3d^2(^1S)4s\ ^2S$ has been discarded. This term has now been found at 31787 cm^{-1}, only 110 cm^{-1} above the position predicted in the generalized least squares fit by Shadmi et al [8].

In the d^3configuration two ^2D terms appear, having the seniority quantum numbers 1 and 3. We use here the same designation as Corliss

and Sugar [3], i.e. $^2D1$ and $^2D2$ have the seniorities 1 and 3 respectively. The upper term, $^2D1$ has been found about 750 cm^{-1} above the position predicted by Shadmi et al [8].

The eigenvector compositions of $(3d + 4s)^3$ shown in Table III are obtained from a parametric study of the whole configuration complex.

3.2 The odd configurations.

The overlap and mixing of the Ti II configurations 3d4s4p and $3d^2np$, n = 4 and 5, has been discussed in a general survey of the singly ionized iron group elements [4]. A parametric fit gives a set of Slater parameters which have been reported in [4]. The eigenvector composition of $3d^24p$ is shown in Table IV. The fitted parameters give a good description of the included configurations, except the highest ^2P term of 3d4s4p which is found 1200 cm^{-1} below the predicted position. This is supposedly caused by $4s^24p$ ^2P [4].

The levels of 3d4s4p appear in two groups some 15000 cm^{-1} apart. These levels were previously [1] designated according to the scheme $3d4s(^1D)4p$ and $3d4s(^3D)4p$ for the upper and lower group respectively. The fact that this designation is inadequate is evident from the Ti III term structure, as the 3d4s singlet - triplet splitting is only about 3500 cm^{-1}. The distance between the two groups is better correlated to the Ti III 4s4p splitting of about 20000 cm^{-1}, indicating that the coupling scheme $3d(^2D)4s4p(^1P)$ and $3d(^2D)4s4p(^3P)$ is more adequate. The same fact is revealed by the fitted Slater parameters, where $G^1(4s4p)$ has the value 25623 cm^{-1}, while $G^2(3d4s)$ is only 8030 cm^{-1}. This has also been pointed out by Roth [9], and his designations were used in the compilation by Corliss and Sugar [3].

The corresponding case was discussed by Johansson in Fe II [5], where the strong 4s4p interaction was found to affect the intensities. A Ti II transition array showing the same intensity relations is seen in Fig 2.

Slater parameters fitted to the $3d^2(^3F)4f$ configuration are given in ref [4]. The relation between $F^2(3d4f)$ and ζ_d, 500 cm^{-1} and 120 cm^{-1} indicates that LS-coupling is not a good approximation. A study

of the eigenvector composition confirms this, and the LS names given to the 4f levels in Table IV have little significance. The F^2/ζ_d ratio is, however, too large to make jK-coupling more useful.

3.3 The high even configurations.

A convergence diagram of the $3d^2(^3F)ns$ series is shown in Fig 3. The smooth curves indicate that 4s, 5s and 6s are not affected by any large perturbations.

Slater parameters of $3d^2(^3F)4d$ are given in [4]. The observed levels are well described in LS-coupling and no significant perturbations are revealed.

Acknowledgements.

The parametric calculations have been carried out with the program chain constructed at Laboratoire Aimé Cotton by Bordarier and Bachelier-Carlier.

References.

1. Russell, H.N., Astroph. J. 66, 283 (1927).
2. Moore, Ch.E., Atomic Energy Levels, Nat. Bur. Std. Circ. 467 Vol I (1949).
3. Corliss, C. and Sugar, J., J. Phys. Chem. Ref. Data, Vol. 8, No. 1, 1 (1979).
4. Johansson, S., Litzén, U., Sinzelle, J. and Wyart, J.F., Physica Scripta 21, 40 (1980).
5. Johansson, S., Physica Scripta 18, 217 (1978).
6. Johansson, S. and Litzén, U., Physica Scripta 22, 49 (1980).
7. Movahed-Ardabili, R., The vacuum ultraviolet spectrum of titanium. Diss., Georgetown University, Washington D.C. 1970.
8. Shadmi, Y., Oreg, J. and Stein, J., J. Opt. Soc. Am. 58, 914 (1968)
9. Roth, C., J. Res. Nat. Bur. Std. 73A, 159 (1969).

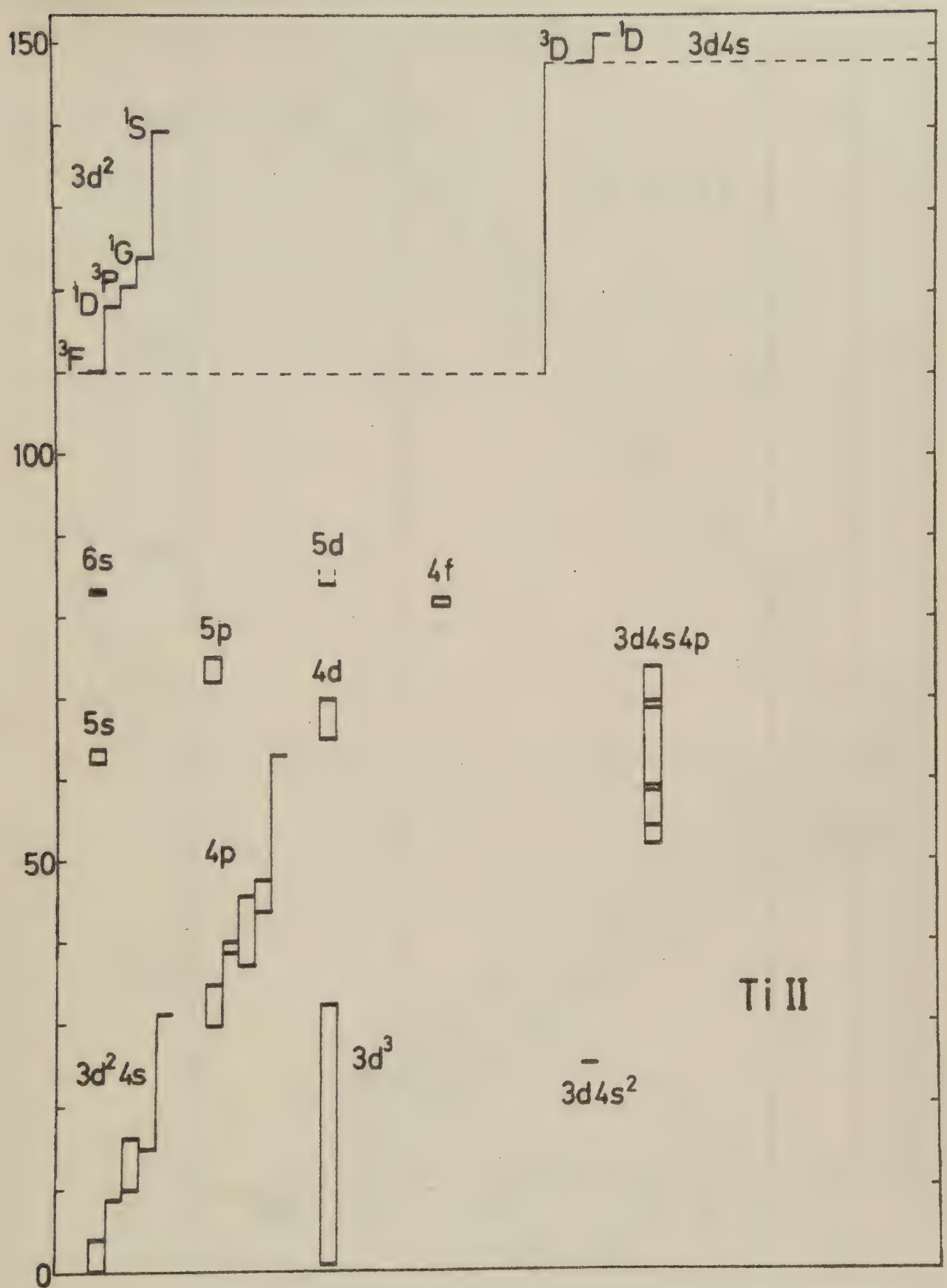

Fig 1. Survey over the Ti II term system

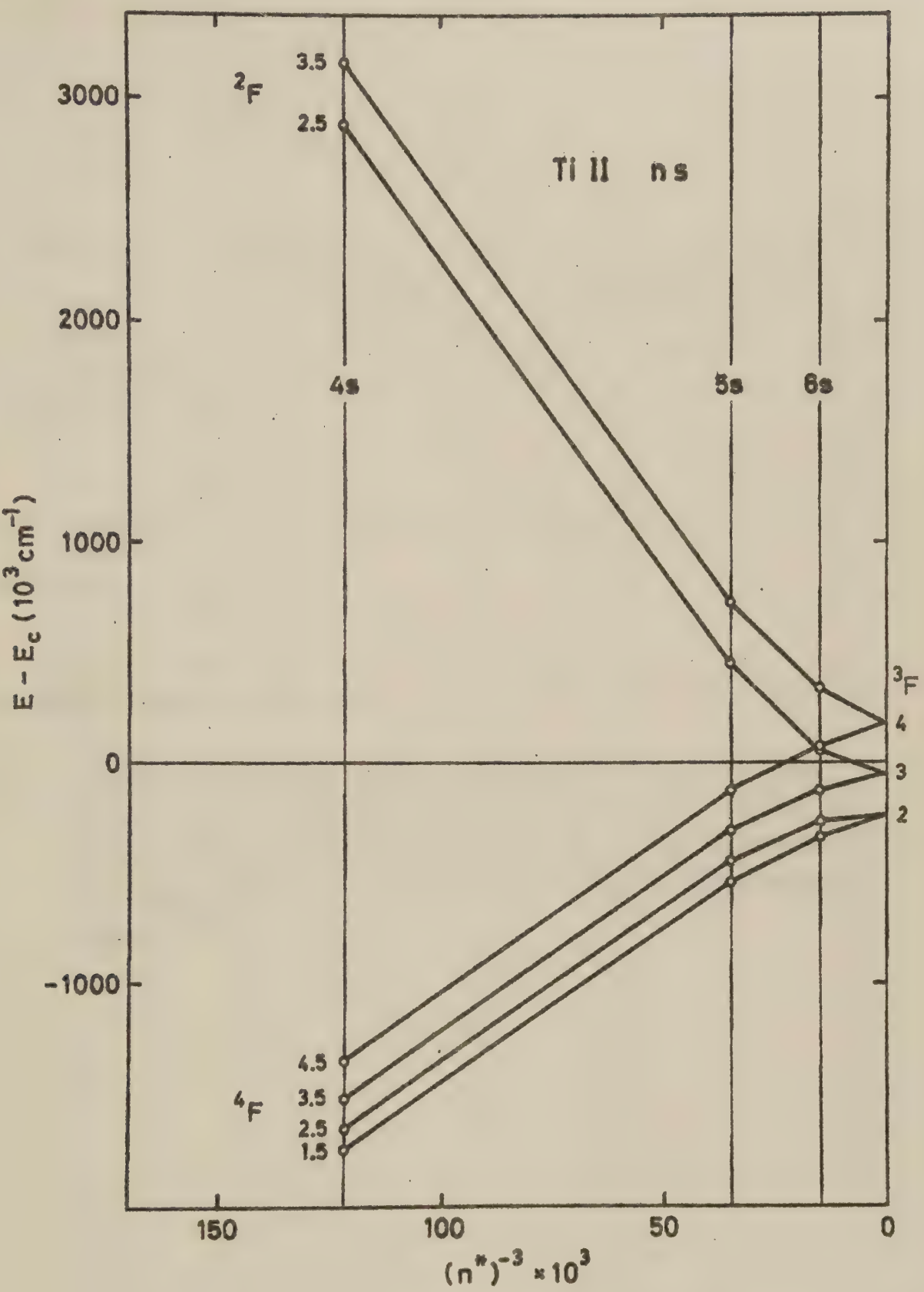

Fig 2. Convergence diagram for $3d^2$ (^3F)ns, indicating that 4s, 5s and 6s are unperturbed.

	$3d(^2D)4s4p(^3P)\ ^2D$ 5/2	3/2	$3d(^2D)4s4p(^1P)\ ^2D$ 5/2	3/2
$3d(^2D)4s^2(^1S)\ ^2D_{5/2}$	0	-	12	4
3/2	-	-	4	11
$3d^2(^1D)4s\ ^2D_{5/2}$	13	9	3	0
3/2	8	12	-	3

Fig. 3 Transition array showing that $3d(^2D)4s4p(^1P)\ ^2D$ gives strong transitions to $3d(^2D)4s^2(^1S)\ ^2D$ as expected, while $4s4p(^3P)\ ^2D$ is more readily deexcited to $3d^24s\ ^2D$. The strong sp interaction thus seems to give a selection rule for the intermediate sp (SL) term.

Table I: Observed Ti II lines above 2500 Å.

Int.	λ_{air}(Å)	σ(cm^{-1}) Obs.	Calc.	Transition Configurations	Levels
0	10319.772	9687.48	7.47	(3F)5s - (3F)5p	e2F3.5 - 2G4.5
3	9983.458	10013.82	3.82	(3F)5s - (3F)5p	e4F4.5 - 4D3.5
3	9956.698	10040.74	0.73	(3F)5s - (3F)5p	e4F3.5 - 4D2.5
1	9931.845	10065.86	5.82	(3F)5s - (3F)5p	e4F2.5 - 4D1.5
0	9921.861	10075.99	5.99	(3F)5s - (3F)5p	e2F3.5 - 2F2.5
1	9907.934	10090.16	0.15	(3F)5s - (3F)5p	e4F1.5 - 4D0.5
1	9841.927	10157.83	7.82	(3F)5s - (3F)5p	e4F1.5 - 4D1.5
1	9821.152	10179.31	9.36	(3F)5s - (3F)5p	e4F2.5 - 4D2.5
0	9803.099	10198.06	8.07	(3F)5s - (3F)5p	e4F3.5 - 4D3.5
3	9654.715	10354.79	4.79	(3F)5s - (3F)5p	e2F3.5 - 2F3.5
3	9625.890	10385.80	5.80	(3F)5p - (3F)6s	2G4.5 - 2F3.5
1	9567.276	10449.43	9.48	(3F)5p - (3F)6s	4D3.5 - 4F3.5
0	9555.269	10462.56	2.57	(3F)5p - (3F)6s	4D2.5 - 4F2.5
0	9520.217	10501.08	1.11	(3F)5p - (3F)6s	4D1.5 - 4F1.5
2	9452.670	10576.12	6.11	(3F)5p - (3F)6s	4D1.5 - 4F2.5
6	9432.144	10599.14	9.15	d3 - (3F)4p	b2F3.5 - z2F3.5
3	9425.377	10606.74	6.81	(3F)5p - (3F)6s	4D2.5 - 4F3.5
0	9403.301	10631.65	1.65	(3F)5s - (3F)5p	e2F2.5 - 2F3.5
4	9388.654	10648.23	8.19	(3F)5p - (3F)6s	4D3.5 - 4F4.5
1	9262.356	10793.43	3.39	(3F)5p - (3F)6s	4D2.5 - 2F2.5
10	9252.532	10804.39	4.89	d3 - (3F)4p	b2F2.5 - z2D1.5
1	9145.214	10931.68	1.63	(3F)5p - (3F)6s	4F4.5 - 4F3.5
0	9126.727	10953.62	3.80	(3F)5p - (3F)6s	4F3.5 - 4F2.5
0	9027.821	11073.83	3.85	d3 - (3F)4p	b2F2.5 - z2D2.5
0	9016.063	11088.27	8.23	(3F)5p - (3F)6s	4F2.5 - 4F2.5
0	9008.146	11098.02	8.05	(3F)5p - (3F)6s	4F3.5 - 4F3.5
1	8982.020	11130.30	0.34	(3F)5p - (3F)6s	4F4.5 - 4F4.5
4	8979.169	11133.83	3.31	d3 - (3F)4p	b2F3.5 - z2D2.5
4	8926.754	11199.20	9.21	(3F)5s - (3F)5p	e2F3.5 - 2D2.5
3	8918.429	11209.66	9.66	(3F)5s - (3F)5p	e2F2.5 - 2D1.5
2	8838.617	11310.88	0.87	(3F)5p - (3F)6s	4G4.5 - 4F3.5
2	8838.417	11311.14	1.15	(3F)5p - (3F)6s	4G5.5 - 4F4.5
3	8825.224	11328.05	8.03	(3F)5p - (3F)6s	4G3.5 - 4F2.5
3	8786.836	11377.54	7.50	(3F)5p - (3F)6s	4G2.5 - 4F1.5
1	8729.342	11452.47	2.50	(3F)5p - (3F)6s	4G2.5 - 4F2.5
1	8714.295	11472.25	2.27	(3F)5p - (3F)6s	4G3.5 - 4F3.5
1	8648.989	11558.87	8.87	(3F)5p - (3F)6s	4F3.5 - 2F3.5
4	8071.508	12385.85	5.87	(3F)5p - (3F)5d	4F4.5 - 4G4.5
4	8056.174	12409.43	9.42	(3F)5p - (3F)5d	4F3.5 - 4G3.5
4	8034.453	12442.98	2.97	(3F)5p - (3F)5d	4F2.5 - 4G2.5
5	7994.386	12505.34	5.33	(3F)5p - (3F)5d	4F4.5 - 4G5.5
9	7953.546	12569.55	9.56	d3 - (3P)4p	d2D2.5 - x2D2.5
5	7945.682	12581.99	1.98	d3 - (3P)4p	d2D2.5 - x2D1.5
8	7909.615	12639.36	9.38	d3 - (3P)4p	d2D1.5 - x2D1.5
7	7880.443	12686.15	6.14	(3F)5p - (3F)5d	4G5.5 - 4G5.5
4	7869.327	12704.12	4.12	(3F)5p - (3F)5d	4G2.5 - 4H3.5
5	7856.797	12724.33	4.32	(3F)4d - (3F)4f	f4F3.5 - 4H4.5
6	7845.113	12743.28	3.30	(3F)5p - (3F)5d	4G4.5 - 4H5.5
6	7842.161	12748.08	8.08	(3F)5p - (3F)5d	4G3.5 - 4H4.5
8	7831.690	12765.12	5.11	(3F)5p - (3F)5d	4G4.5 - 4G4.5

9	7824.909	12776.19	6.19	(3F)5p	-	(3F)5d	4G5.5	- 4H6.5
7	7820.355	12783.64	3.64	(3F)5p	-	(3F)5d	4G3.5	- 4G3.5
7	7805.977	12807.17	7.19	(3F)5p	-	(3F)5d	4G2.5	- 4G2.5
6	7786.439	12839.31	9.29	(3F)4d	-	(3F)4f	f4F2.5	- 2G3.5
7	7759.094	12884.56	4.57	(3F)5p	-	(3F)5d	4G4.5	- 4G5.5
4	7755.740	12890.13	0.11	(3F)4d	-	(3F)4f	f4F3.5	- 2G4.5
4	7733.333	12927.48	7.46	(3F)4d	-	(3F)4f	f4F2.5	- 4F2.5
7	7716.900	12955.01	4.99	(3F)4d	-	(3F)4f	f4F1.5	- 4G2.5
5	7713.361	12960.95	0.94	(3F)4d	-	(3F)4f	f4F3.5	- 4F3.5
7	7706.773	12972.03	2.01	(3F)4d	-	(3F)4f	f4F3.5	- 2H4.5
4	7693.740	12994.00	3.98	(3F)4d	-	(3F)4f	f4F4.5	- 4G4.5
7	7681.718	13014.34	4.32	(3F)4d	-	(3F)4f	f4F2.5	- 4G3.5
9	7679.201	13018.60	8.62	(3F)4d	-	(3F)4f	f4F4.5	- 4G5.5
3	7677.693	13021.16	1.18	(3F)4d	-	(3F)4f	f4F2.5	- 4P1.5
5	7667.959	13037.69	7.70	(3F)4d	-	(3F)4f	f4F1.5	- 4F1.5
4	7661.002	13049.53	9.54	(3F)4d	-	(3F)4f	f4F4.5	- 4D3.5
9	7653.040	13063.11	3.10	(3F)4d	-	(3F)4f	f4F4.5	- 4F4.5
3	7651.131	13066.37	6.40	(3F)4d	-	(3F)4f	f4F2.5	- 4F3.5
3	7588.607	13174.02	4.07	(3F)4d	-	(3F)4f	f4F1.5	- 2F2.5
4	7584.010	13182.01	2.01	(3F)4d	-	(3F)4f	f4F3.5	- 4D3.5
4	7576.235	13195.54	5.57	(3F)4d	-	(3F)4f	f4F3.5	- 4F4.5
8	7575.413	13196.97	6.95	d3	-	(3P)4p	d2D1.5	- y2P0.5
4	7574.065	13199.32	9.33	(3F)4d	-	(3F)4f	f4F3.5	- 2F3.5
10	7564.494	13216.02	6.03	d3	-	(3P)4p	d2D2.5	- y2P1.5
5	7557.820	13227.69	7.65	(3F)4d	-	(3F)4f	f4F1.5	- 4P2.5
6	7531.769	13273.44	3.44	d3	-	(3P)4p	d2D1.5	- y2P1.5
5	7519.899	13294.39	4.39	(3F)4d	-	(3F)4f	f4F3.5	- 4D2.5
4	7456.650	13407.16	7.11	(3F)4d	-	(3F)4f	e2H4.5	- 4I4.5
4	7455.279	13409.62	9.59	(3F)4d	-	(3F)4f	2D1.5	- 4F2.5
3	7451.316	13416.75	6.73	(3F)4d	-	(3F)4f	e2H5.5	- 2I5.5
5	7447.871	13422.96	2.95	(3F)4d	-	(3F)4f	e2H4.5	- 4H5.5
3	7411.637	13488.58	8.56	(3F)4d	-	(3F)4f	e2H5.5	- 4H6.5
3	7403.527	13503.36	3.31	(3F)4d	-	(3F)4f	2D1.5	- 4P1.5
5	7397.489	13514.38	4.43	(3F)4d	-	(3F)4f	2D2.5	- 4P2.5
5	7373.459	13558.42	8.44	(3F)4d	-	(3F)4f	e2H4.5	- 4I5.5
6	7362.351	13578.88	8.86	(3F)4d	-	(3F)4f	2D1.5	- 2F2.5
8	7355.432	13591.65	1.64	d3	-	(3F)4p	b2F2.5	- z2G3.5
5	7354.733	13592.94	2.97	(3F)4d	-	(3F)4f	e2H4.5	- 2H4.5
6	7351.470	13598.97	9.03	(3F)4d	-	(3F)4f	e2H5.5	- 2H5.5
5	7323.152	13651.56	1.60	d3	-	(3F)4p	b2F3.5	- z2G3.5
6	7313.863	13668.90	8.90	(3F)4d	-	(3F)4f	2D2.5	- 2F3.5
9	7313.292	13669.97	9.99	(3F)4d	-	(3F)4f	e2H4.5	- 2I5.5
5	7305.516	13684.52	4.53	(1S)4s	-	(3P)4p	a2S0.5	- y2P0.5
10	7297.282	13699.96	9.94	(3F)4d	-	(3F)4f	e2H5.5	- 2I6.5
5	7296.687	13701.08	1.08	(3F)4d	-	(3F)4f	2D1.5	- 2D1.5
4	7272.104	13747.39	7.40	(3F)4d	-	(3F)4f	e2H4.5	- 4G4.5
6	7264.904	13761.02	1.01	(1S)4s	-	(3P)4p	a2S0.5	- y2P1.5
7	7225.266	13836.51	6.50	(3F)4d	-	(3F)4f	2D2.5	- 2D2.5
6	7217.012	13852.33	2.29	(3F)4d	-	(3F)4f	e2H4.5	- 2H5.5
10	7214.718	13856.73	6.74	d3	-	(3F)4p	b2F3.5	- z2G4.5
5	7198.677	13887.61	7.56	(3F)4d	-	(3F)4f	2D2.5	- 2P1.5
5	7138.096	14005.48	5.58	(3F)4d	-	(3F)4f	2D1.5	- 2P1.5
9	7130.960	14019.49	9.60	(3F)4d	-	(3F)4f	e2G4.5	- 2G4.5
4	7129.891	14021.60	1.60	(3F)4d	-	(3F)4f	e2G3.5	- 4H3.5
4	7120.330	14040.42	0.49	s2	-	(1D)4p	c2D2.5	- z2P1.5
4	7106.885	14066.98	6.98	(3F)4d	-	(3F)4f	e2G4.5	- 4I5.5

5	7105.237	14070.24	0.26	(3F)4d - (3F)4f	e2G3.5 -	4H4.5
6	7100.416	14079.80	9.77	(3F)4d - (3F)4f	e2G3.5 -	2G3.5
7	7074.127	14132.12	2.09	(3F)4d - (3F)4f	e2G3.5 -	4I4.5
6	7050.973	14178.53	8.52	(3F)4d - (3F)4f	e2G4.5 -	2I5.5
5	7013.284	14254.72	4.80	(3F)4d - (3F)4f	e2G3.5 -	4G3.5
7	7012.689	14255.93	5.94	(3F)4d - (3F)4f	e2G4.5 -	4G4.5
11blI	7004.638	14272.32	2.25	s2 - (1D)4p	c2D1.5 -	z2P1.5
11	6998.908	14284.00	4.01	s2 - (1D)4p	c2D2.5 -	y2D2.5
7	6982.307	14317.96	7.94	(3F)4d - (3F)4f	e2G3.5 -	2H4.5
3	6977.000	14328.85	8.82	(3F)4d - (3F)4f	e2G4.5 -	2F3.5
8	6961.431	14360.90	0.83	(3F)4d - (3F)4f	e2G4.5 -	2H5.5
7	6937.687	14410.05	9.96	s2 - (1D)4p	c2D2.5 -	y2D1.5
6	6907.804	14472.39	2.38	(3F)4d - (3F)4f	e2G3.5 -	4G4.5
6	6827.951	14641.64	1.72	s2 - (1D)4p	c2D1.5 -	y2D1.5
4	6794.537	14713.65	3.63	s2 - (1D)4p	c2D1.5 -	z2P0.5
5	6785.219	14733.85	3.87	s2 - (1D)4p	c2D2.5 -	y2F2.5
14	6717.808	14881.70	1.73	s2 - (1D)4p	c2D2.5 -	y2F3.5
11	6680.144	14965.60	5.63	s2 - (1D)4p	c2D1.5 -	y2F2.5
5	6673.739	14979.97	9.98	(3F)4d - (3F)4f	2P1.5 -	4F2.5
7	6606.962	15131.37	1.40	(3P)4s - (3F)4p	b2P1.5 -	z2D1.5
11	6605.889	15133.83	3.81	d3 - (1G)4p	d2D2.5 -	x2F3.5
6	6575.907	15202.83	2.83	(3F)4d - (3F)4f	2P1.5 -	4P2.5
7	6565.522	15226.87	6.93	(3F)4d - (3F)4f	2P1.5 -	4D1.5
11	6559.582	15240.66	0.66	(3P)4s - (3F)4p	b2P0.5 -	z2D1.5
7	6537.495	15292.15	2.16	d3 - (1G)4p	d2D2.5 -	x2F2.5
6	6514.275	15346.66	6.69	(3F)4d - (3F)4f	2P0.5 -	4P1.5
10	6513.032	15349.59	9.56	d3 - (1G)4p	d2D1.5 -	x2F2.5
6	6496.495	15388.66	8.70	s2 - (3P)4p	c2D2.5 -	y4D2.5
15	6491.546	15400.40	0.36	(3P)4s - (3F)4p	b2P1.5 -	z2D2.5
13	6445.571	15510.24	0.24	(3F)4d - (3F)4f	2P1.5 -	4S1.5
11	6439.493	15524.88	4.90	(3F)4d - (3F)4f	2P1.5 -	2D2.5
9	6431.378	15544.47	4.46	(3F)4d - (3F)4f	2P0.5 -	2D1.5
9	6418.348	15576.03	5.96	(3F)4d - (3F)4f	2P1.5 -	2P1.5
6	6406.212	15605.54	5.51	s2 - (3P)4p	c2D2.5 -	y4D3.5
5	6219.926	16072.92	2.88	(3P)4s - (3F)4p	b2P1.5 -	z4D2.5
6	6194.339	16139.31	9.40	(3F)4d - (3F)4f	e4D3.5 -	4I4.5
5	6164.920	16216.32	6.29	(3F)4d - (3F)4f	f2F3.5 -	4H4.5
7	6154.684	16243.29	3.35	(3F)4d - (3F)4f	e4D3.5 -	2G4.5
7	6141.545	16278.04	8.12	(3F)4d - (3F)4f	f2F3.5 -	4I4.5
6	6133.509	16299.37	9.27	(3F)4d - (3F)4f	e4H6.5 -	4I5.5
4	6130.373	16307.71	7.71	(3F)4d - (3F)4f	e4H5.5 -	4H5.5
6	6123.807	16325.19	5.25	(3F)4d - (3F)4f	e4D3.5 -	2H4.5
7	6107.818	16367.93	8.00	(3F)4d - (3F)4f	e4H4.5 -	4H4.5
11	6106.512	16371.43	1.54	(3F)4d - (3F)4f	f2F2.5 -	2G3.5
9	6102.558	16382.04	2.08	(3F)4d - (3F)4f	f2F3.5 -	2G4.5
7	6080.713	16440.89	0.89	(3F)4d - (3F)4f	e4H3.5 -	4H3.5
7	6079.881	16443.14	3.20	(3F)4d - (3F)4f	e4H5.5 -	4I5.5
8	6078.953	16445.65	5.68	(3F)4d - (3F)4f	e4H4.5 -	4H5.5
8	6076.266	16452.92	2.91	(3F)4d - (3F)4f	f2F3.5 -	4F3.5
8	6073.765	16459.70	9.71	(3F)4d - (3F)4f	f2F2.5 -	4F2.5
9	6072.434	16463.30	3.28	(3F)4d - (3F)4f	e4D2.5 -	4G3.5
11	6068.728	16473.36	3.31	(3F)4d - (3F)4f	e4H5.5 -	4I6.5
8	6066.380	16479.73	9.69	(3F)4d - (3F)4f	e4D3.5 -	4G4.5
8	6065.342	16482.55	2.64	(3F)4d - (3F)4f	e4H6.5 -	4H6.5
6	6062.755	16489.59	9.55	(3F)4d - (3F)4f	e4H3.5 -	4H4.5
7	6059.149	16499.40	9.38	(3F)4d - (3F)4f	e4D1.5 -	4F2.5

5	6054.203	16512.88	2.87	(3F)4d	-	(3F)4f	e4H6.5	- 4G5.5
7	6053.304	16515.33	5.36	(3F)4d	-	(3F)4f	e4D2.5	- 4F3.5
8	6046.531	16533.83	3.79	(3F)4d	-	(3F)4f	e4H4.5	- 2G4.5
9	6045.993	16535.30	5.26	(3F)4d	-	(3F)4f	e4D3.5	- 4D3.5
7	6045.253	16537.33	7.43	(3F)4d	-	(3F)4f	e4H3.5	- 4G2.5
8	6042.181	16545.73	5.69	(3F)4d	-	(3F)4f	e4D2.5	- 2F2.5
5	6041.872	16546.58	6.57	(3F)4d	-	(3F)4f	f2F2.5	- 4G3.5
9	6041.035	16548.87	8.81	(3F)4d	-	(3F)4f	e4D3.5	- 4F4.5
10	6040.076	16551.50	1.39	(3F)4d	-	(3F)4f	e4H3.5	- 4I4.5
9	6039.684	16552.57	2.54	(3F)4d	-	(3F)4f	e4H4.5	- 4G3.5
9	6039.684	16552.57	2.58	(3F)4d	-	(3F)4f	e4D3.5	- 2F3.5
11	6029.271	16581.16	1.17	(3F)4d	-	(3F)4f	e4H4.5	- 4I5.5
7	6024.935	16593.09	3.08	(3F)4d	-	(3F)4f	e4D0.5	- 4F1.5
7	6024.935	16593.09	3.10	(3F)4d	-	(3F)4f	e4D1.5	- 4P1.5
7	6024.935	16593.09	3.12	(3F)4d	-	(3F)4f	e4H6.5	- 2H5.5
4	6022.904	16598.69	8.63	(3F)4d	-	(3F)4f	e4G5.5	- 2G4.5
4	6022.904	16598.69	8.65	(3F)4d	-	(3F)4f	f2F2.5	- 4F3.5
5	6022.690	16599.28	9.27	(3F)4d	-	(3F)4f	e4D2.5	- 4P2.5
4	6020.728	16604.69	4.63	(3F)4d	-	(3F)4f	e4H4.5	- 4F3.5
6	6015.751	16618.42	8.41	(3F)4d	-	(3F)4f	f2F3.5	- 4G4.5
12	6012.752	16626.72	6.71	(3F)4d	-	(3F)4f	e4H6.5	- 4I7.5
5	6011.918	16629.02	8.98	(3F)4d	-	(3F)4f	f2F2.5	- 2F2.5
4	6010.790	16632.14	2.16	(3F)4d	-	(3F)4f	e4H5.5	- 4G4.5
6	6007.103	16642.35	2.33	(3F)4d	-	(3F)4f	e4G4.5	- 4I4.5
6	6005.792	16645.98	6.00	(3F)4d	-	(3F)4f	e4G5.5	- 4I5.5
6	6005.186	16647.66	7.64	(3F)4d	-	(3F)4f	e4D3.5	- 4D2.5
9	6002.398	16655.40	5.34	(3F)4d	-	(3F)4f	e4H3.5	- 2G4.5
6	6001.871	16656.86	6.79	(3F)4d	-	(3F)4f	e4H5.5	- 4G5.5
12	6001.387	16658.20	8.17	(3F)4d	-	(3F)4f	e4G4.5	- 4H5.5
10	5994.955	16676.07	6.12	(3F)4d	-	(3F)4f	e4G5.5	- 4I6.5
5	5992.623	16682.56	2.56	(3F)4d	-	(3F)4f	f2F2.5	- 4P2.5
8	5989.461	16691.37	1.30	(3F)4d	-	(3F)4f	f2F3.5	- 2F3.5
6	5985.907	16701.28	1.28	(3F)4d	-	(3F)4f	e4H5.5	- 4F4.5
5	5983.959	16706.72	6.67	(3F)4d	-	(3F)4f	e4G3.5	- 2G3.5
5	5983.959	16706.72	6.66	(3F)4d	-	(3F)4f	f2F2.5	- 4D1.5
5	5979.115	16720.25	0.18	(3F)4d	-	(3F)4f	e4D3.5	- 2D2.5
4	5973.331	16736.44	6.42	(3F)4d	-	(3F)4f	e4D2.5	- 4D3.5
5	5973.038	16737.26	7.25	(3F)4d	-	(3F)4f	e4H3.5	- 2H4.5
13	5971.647	16741.16	1.16	(3F)4d	-	(3F)4f	e4G2.5	- 4H3.5
6	5969.792	16746.36	6.29	(3F)4d	-	(3F)4f	e4G4.5	- 2G4.5
6	5969.792	16746.36	6.34	(3F)4d	-	(3F)4f	e4D1.5	- 4D1.5
4	5968.057	16751.23	1.20	(3F)4d	-	(3F)4f	f2F2.5	- 2D1.5
4	5967.179	16753.70	3.74	(3F)4d	-	(3F)4f	e4D2.5	- 2F3.5
4	5965.288	16759.01	8.99	(3F)4d	-	(3F)4f	e4G3.5	- 4I4.5
4	5961.643	16769.25	9.25	(3F)4d	-	(3F)4f	e4D1.5	- 4P0.5
6	5955.572	16786.35	6.26	d3	-	(3F)4p	b2D2.5	- z4G2.5
6	5955.572	16786.35	6.36	(3F)4d	-	(3F)4f	f2F3.5	- 4D2.5
5	5953.979	16790.84	0.87	(3F)4d	-	(3F)4f	e4D1.5	- 2D1.5
6	5952.593	16794.75	4.83	(3F)4d	-	(3F)4f	e4G3.5	- 4F2.5
6	5952.593	16794.75	4.75	(3F)4d	-	(3F)4f	e4D0.5	- 4D0.5
6	5952.593	16794.75	4.76	(3F)4d	-	(3F)4f	e4H4.5	- 4G5.5
6	5950.986	16799.28	9.33	(3F)4d	-	(3F)4f	e4G2.5	- 2G3.5
8	5940.330	16829.42	9.38	(3F)4d	-	(3F)4f	e4G5.5	- 4H6.5
8	5937.390	16837.75	7.69	(3F)4d	-	(3F)4f	e4G2.5	- 4G2.5
8	5937.328	16837.93	7.96	(3F)4d	-	(3F)4f	e4H5.5	- 2I6.5
5	5933.503	16848.78	8.80	(3F)4d	-	(3F)4f	e4D2.5	- 4D2.5

8	5929.696	16859.60	9.60	(3F)4d - (3F)4f	e4G5.5 -	4G5.5
6	5928.503	16862.99	2.94	(3F)4d - (3F)4f	e4G3.5 -	2G4.5
5	5924.278	16875.02	5.02	(3F)4d - (3F)4f	e4H4.5 -	2H5.5
5	5919.905	16887.48	7.50	(3F)4d - (3F)4f	e4G2.5 -	4F2.5
5	5914.081	16904.11	4.08	(3F)4d - (3F)4f	e4G5.5 -	4F4.5
5	5910.082	16915.55	5.65	d3 - (3F)4p	b2D1.5 -	z4G2.5
4	5903.723	16933.77	3.78	(3F)4d - (3F)4f	e4G3.5 -	4F3.5
5	5901.629	16939.78	9.85	(3F)4d - (3F)4f	e4G5.5 -	2H5.5
4	5890.287	16972.40	2.40	(3F)4d - (3F)4f	e4D2.5 -	2P1.5
5	5889.599	16974.38	4.36	(3F)4d - (3F)4f	e4G2.5 -	4G3.5
4	5888.893	16976.42	6.42	d3 - (3F)4p	b2D2.5 -	z4G3.5
4	5887.239	16981.19	1.22	(3F)4d - (3F)4f	e4G2.5 -	4P1.5
6	5886.751	16982.59	2.62	(3F)4d - (3F)4f	e4G4.5 -	4G4.5
4	5879.142	17004.57	4.63	(3F)4d - (3F)4f	f2F2.5 -	2D2.5
5	5878.225	17007.22	7.26	(3F)4d - (3F)4f	e4G4.5 -	4G5.5
4	5867.548	17038.17	8.19	(3F)4d - (3F)4f	e4G4.5 -	4D3.5
5	5862.887	17051.72	1.74	(3F)4d - (3F)4f	e4G4.5 -	4F4.5
4	5861.595	17055.48	5.51	(3F)4d - (3F)4f	e4G4.5 -	2F3.5
4	5846.591	17099.24	9.28	(3F)4d - (3F)4f	e4G3.5 -	4G4.5
10	5529.983	18078.22	8.21	d3 - (3F)4p	b2D2.5 -	z4F1.5
15	5492.849	18200.43	0.39	d3 - (3F)4p	b2D2.5 -	z4F2.5
13	5490.663	18207.68	7.59	d3 - (3F)4p	b2D1.5 -	z4F1.5
14	5476.642	18254.29	4.31	(3P)4p - (3F)5s	x2D1.5 -	e2F2.5
10	5454.070	18329.84	9.78	d3 - (3F)4p	b2D1.5 -	z4F2.5
12	5418.752	18449.30	9.31	d3 - (3F)4p	b2D2.5 -	z2F2.5
14	5391.177	18543.67	3.59	(3P)4p - (3F)5s	x2D2.5 -	e2F3.5
12	5381.009	18578.71	8.70	d3 - (3F)4p	b2D1.5 -	z2F2.5
9	5379.141	18585.16	5.14	d3 - (1D)4p	b2F3.5 -	y2D2.5
5	5360.118	18651.12	1.12	d3 - (1D)4p	b2F2.5 -	y2D1.5
12	5336.778	18732.69	2.70	d3 - (3F)4p	b2D2.5 -	z2F3.5
16	5268.607	18975.07	5.03	d3 - (1D)4p	b2F2.5 -	y2F2.5
16	5262.131	18998.42	8.40	d3 - (3F)4p	b2D2.5 -	z2D1.5
12	5227.858	19122.97	2.90	d3 - (1D)4p	b2F2.5 -	y2F3.5
15	5226.533	19127.81	7.79	d3 - (3F)4p	b2D1.5 -	z2D1.5
14	5211.516	19182.93	2.86	d3 - (1D)4p	b2F3.5 -	y2F3.5
15	5188.691	19267.31	7.36	d3 - (3F)4p	b2D2.5 -	z2D2.5
14	5185.902	19277.68	7.64	(1G)4s - (3F)4p	b2G3.5 -	z2G3.5
14	5154.059	19396.78	6.75	d3 - (3F)4p	b2D1.5 -	z2D2.5
10	5131.303	19482.80	2.78	(1G)4s - (3F)4p	b2G3.5 -	z2G4.5
14	5129.155	19490.96	0.97	(1G)4s - (3F)4p	b2G4.5 -	z2G4.5
12	5083.738	19665.08	5.05	(1G)4p - (3F)5s	y2G4.5 -	e2F3.5
14	5072.271	19709.54	9.50	s2 - (3P)4p	c2D2.5 -	x2D2.5
13	5069.090	19721.91	1.91	s2 - (3P)4p	c2D2.5 -	x2D1.5
5	5022.062	19906.59	6.64	d3 - (3P)4p	b2F3.5 -	y4D3.5
11	5013.679	19939.87	9.88	d3 - (3F)4p	b2D2.5 -	z4D2.5
13	5010.199	19953.72	3.67	s2 - (3P)4p	c2D1.5 -	x2D1.5
10	5005.159	19973.81	3.82	d3 - (3F)4p	b2D1.5 -	z4D1.5
14	4911.175	20356.04	5.95	s2 - (3P)4p	c2D2.5 -	y2P1.5
12	4874.005	20511.27	1.24	s2 - (3P)4p	c2D1.5 -	y2P0.5
7	4865.615	20546.65	6.66	d3 - (3F)4p	a2G3.5 -	z4G2.5
6	4849.170	20616.33	6.28	d3 - (3F)4p	a2G4.5 -	z4G3.5
13	4805.089	20805.45	5.47	(3P)4s - (3P)4p	b2P1.5 -	z2S0.5
7	4798.507	20833.99	3.93	(1D)4s - (3F)4p	a2D1.5 -	z4G2.5
5	4791.492	20864.49	4.48	(1G)4p - (3F)4d	x2F3.5 -	e2H4.5
12	4779.979	20914.74	4.73	(3P)4s - (3P)4p	b2P0.5 -	z2S0.5
7	4764.536	20982.54	2.59	d3 - (3F)4p	a2P1.5 -	z4F2.5

8	4763.892	20985.37	5.42	d3 - (3F)4p	a2P0.5 - z4F1.5
6	4762.790	20990.23	0.29	(1D)4s - (3F)4p	a2D2.5 - z4G3.5
5	4719.533	21182.61	2.70	(3P)4s - (3F)4p	b4P2.5 - z2F2.5
9	4708.651	21231.56	1.51	d3 - (3F)4p	a2P1.5 - z2F2.5
9	4657.212	21466.06	6.09	(3P)4s - (3F)4p	b4P2.5 - z2F3.5
6	4636.341	21562.69	2.80	d3 - (3F)4p	a4P1.5 - z4F2.5
5	4626.994	21606.25	6.31	(3P)4p - (3F)4d	x2D1.5 - 2P0.5
15	4589.915	21780.79	0.59	d3 - (3F)4p	a2P1.5 - z2D1.5
7	4583.408	21811.71	1.72	d3 - (3F)4p	a4P1.5 - z2F2.5
6	4580.449	21825.80	5.82	(3P)4s - (3F)4p	b4P1.5 - z2D1.5
19	4571.957	21866.34	6.29	d3 - (3F)4p	a2H4.5 - z2G3.5
7	4568.310	21883.80	3.79	(3P)4s - (3F)4p	b4P0.5 - z2D1.5
5	4566.673	21891.64	1.72	(3P)4p - (3F)4d	x2D2.5 - 2P1.5
16	4563.770	21905.57	5.61	d3 - (3F)4p	a2P0.5 - z2D1.5
15	4549.612	21973.74	3.71	d3 - (3F)4p	a2H5.5 - z2G4.5
7	4544.018	22000.79	0.75	(3P)4s - (3F)4p	b4P2.5 - z2D2.5
15	4533.972	22049.53	9.56	d3 - (3F)4p	a2P1.5 - z2D2.5
9	4529.480	22071.40	1.43	d3 - (3F)4p	a2H4.5 - z2G4.5
5	4525.243	22092.07	2.07	(1D)4s - (3F)4p	a2D2.5 - z4F1.5
6	4524.701	22094.71	4.79	(3P)4s - (3F)4p	b4P1.5 - z2D2.5
6	4518.348	22125.78	5.88	(1D)4s - (3F)4p	a2D1.5 - z4F1.5
15	4501.269	22209.73	9.72	d3 - (3F)4p	a2G3.5 - z2F2.5
5	4500.369	22214.17	4.26	(1D)4s - (3F)4p	a2D2.5 - z4F2.5
5	4493.529	22247.98	8.07	(1D)4s - (3F)4p	a2D1.5 - z4F2.5
17	4488.342	22273.69	3.75	s2 - (1G)4p	c2D2.5 - x2F3.5
11	4470.835	22360.91	0.81	d3 - (3F)4p	a4P1.5 - z2D1.5
6	4469.116	22369.51	9.40	(1D)4s - (3F)4p	a2D2.5 - z4F3.5
19	4468.517	22372.51	2.56	d3 - (3F)4p	a2G4.5 - z2F3.5
11	4464.461	22392.83	2.90	d3 - (3F)4p	a4P0.5 - z2D1.5
8	4456.632	22432.17	2.09	s2 - (1G)4p	c2D2.5 - x2F2.5
15	4450.503	22463.06	3.18	(1D)4s - (3F)4p	a2D2.5 - z2F2.5
10	4444.536	22493.22	3.11	d3 - (3F)4p	a2G3.5 - z2F3.5
16	4443.775	22497.07	6.99	(1D)4s - (3F)4p	a2D1.5 - z2F2.5
10	4441.731	22507.43	7.42	d3 - (3F)4p	a4P2.5 - z2D2.5
11	4418.306	22626.75	6.63	d3 - (3F)4p	a2P1.5 - z4D1.5
17	4417.715	22629.78	9.77	d3 - (3F)4p	a4P1.5 - z2D2.5
5	4411.922	22659.50	9.48	(3P)4s - (3F)4p	b4P0.5 - z4D0.5
14	4411.096	22663.74	3.85	s2 - (1G)4p	c2D1.5 - x2F2.5
8	4409.514	22671.87	1.86	(3P)4s - (3F)4p	b4P1.5 - z4D1.5
5	4409.244	22673.26	3.26	(3P)4s - (3F)4p	b4P2.5 - z4D2.5
15	4399.786	22722.00	2.07	d3 - (3F)4p	a2P1.5 - z4D2.5
4	4398.251	22729.93	9.82	(3P)4s - (3F)4p	b4P0.5 - z4D1.5
11	4395.833	22742.43	2.35	(3P)4s - (3F)4p	b4P2.5 - z4D3.5
19	4395.004	22746.72	6.57	(1D)4s - (3F)4p	a2D2.5 - z2F3.5
13	4394.018	22751.82	1.65	d3 - (3F)4p	a2P0.5 - z4D1.5
10	4391.043	22767.23	7.30	(3P)4s - (3F)4p	b4P1.5 - z4D2.5
13	4386.846	22789.02	9.02	d3 - (1G)4p	b2F2.5 - y2G3.5
12	4374.836	22851.58	1.69	(3P)4s - (1D)4p	b2P1.5 - y2D2.5
16	4367.654	22889.16	9.13	d3 - (1G)4p	b2F3.5 - y2G4.5
12	4350.846	22977.58	7.63	(3P)4s - (1D)4p	b2P1.5 - y2D1.5
14	4344.299	23012.20	2.26	(1D)4s - (3F)4p	a2D2.5 - z2D1.5
14	4341.367	23027.75	7.77	d3 - (3F)4p	a2G3.5 - z2D2.5
18	4337.876	23046.28	6.07	(1D)4s - (3F)4p	a2D1.5 - z2D1.5
4	4337.254	23049.58	9.55	(3P)4s - (1D)4p	b2P1.5 - z2P0.5
11	4330.723	23084.34	4.49	d3 - (3F)4p	a4P2.5 - z4D1.5
12	4330.234	23086.95	6.89	(3P)4s - (1D)4p	b2P0.5 - y2D1.5

14	4320.957	23136.51	6.50	d3 - (3F)4p	a4P1.5 - z4D0.5
13	4316.802	23158.78	8.81	(3P)4s - (1D)4p	b2P0.5 - z2P0.5
17b1I	4314.965	23168.64	8.59	d3 - (3F)4p	a4P0.5 - z4D0.5
17	4312.874	23179.88	9.94	d3 - (3F)4p	a4P2.5 - z4D2.5
17	4307.865	23206.83	6.84	d3 - (3F)4p	a4P1.5 - z4D1.5
17	4301.923	23238.88	8.93	d3 - (3F)4p	a4P0.5 - z4D1.5
19	4300.064	23248.93	9.02	d3 - (3F)4p	a4P2.5 - z4D3.5
19	4294.094	23281.25	1.23	(1D)4s - (3F)4p	a2D2.5 - z2D2.5
18	4290.216	23302.29	2.29	d3 - (3F)4p	a4P1.5 - z4D2.5
13	4287.875	23315.02	5.04	(1D)4s - (3F)4p	a2D1.5 - z2D2.5
8	4239.669	23580.11	0.12	(3P)4p - (3F)4d	x2D2.5 - 2D2.5
9	4227.353	23648.80	8.81	d3 - (3F)4p	a2G4.5 - z4D3.5
4	4190.164	23858.69	8.30	(1D)4s - (3F)4p	a2D2.5 - z4D1.5
10	4188.984	23865.41	5.40	(1G)4p - (3F)4d	y2G3.5 - e2G3.5
9	4184.309	23892.07	2.11	(1D)4s - (3F)4p	a2D1.5 - z4D1.5
13	4174.053	23950.78	0.66	d3 - (3P)4p	b2F2.5 - x2D2.5
13	4173.531	23953.77	3.75	(1D)4s - (3F)4p	a2D2.5 - z4D2.5
19	4171.919	23963.03	3.08	d3 - (3P)4p	b2F2.5 - x2D1.5
19	4163.634	24010.71	0.63	d3 - (3P)4p	b2F3.5 - x2D2.5
11	4161.527	24022.87	2.82	(1D)4s - (3F)4p	a2D2.5 - z4D3.5
10	4158.273	24041.67	1.70	(1G)4p - (3F)4d	y2G4.5 - e2G4.5
11	4129.148	24211.24	1.18	(1G)4s - (1D)4p	b2G3.5 - y2D2.5
4	4056.187	24646.73	6.72	(3F)4s - (3F)4p	a2F3.5 - z4G2.5
11	4053.829	24661.07	1.04	(1G)4s - (1D)4p	b2G3.5 - y2F2.5
4	4029.681	24808.85	8.90	(1G)4s - (1D)4p	b2G3.5 - y2F3.5
12	4028.355	24817.02	7.10	(1G)4s - (1D)4p	b2G4.5 - y2F3.5
13	4025.120	24836.96	6.89	(3F)4s - (3F)4p	a2F3.5 - z4G3.5
15	4012.396	24915.72	5.79	(3F)4s - (3F)4p	a2F2.5 - z4G2.5
5	3987.614	25070.56	0.65	(3F)4s - (3F)4p	a2F3.5 - z4G4.5
1	3981.986	25106.00	5.88	(3F)4s - (3F)4p	a2F2.5 - z4G3.5
11	3932.020	25425.02	5.00	d3 - (3F)4p	a2G4.5 - z2G3.5
12	3913.477	25545.49	5.55	d3 - (3F)4p	a2G3.5 - z2G3.5
12	3900.559	25630.09	0.14	d3 - (3F)4p	a2G4.5 - z2G4.5
4	3836.084	26060.86	0.86	(3F)4s - (3F)4p	a2F3.5 - z4F2.5
6	3814.581	26207.76	7.74	(3F)4s - (3F)4p	a2F2.5 - z4F1.5
5	3813.394	26215.92	6.00	(3F)4s - (3F)4p	a2F3.5 - z4F3.5
1	3799.787	26309.80	9.78	(3F)4s - (3F)4p	a2F3.5 - z2F2.5
4	3796.885	26329.90	9.92	(3F)4s - (3F)4p	a2F2.5 - z4F2.5
4	3776.059	26475.12	5.17	d3 - (1D)4p	b2D2.5 - z2P1.5
1	3774.651	26484.99	5.07	(3F)4s - (3F)4p	a2F2.5 - z4F3.5
1	3770.396	26514.88	4.91	d3 - (1G)4p	b2F2.5 - x2F3.5
7	3761.882	26574.89	4.87	d3 - (1G)4p	b2F3.5 - x2F3.5
13	3761.326	26578.82	8.85	(3F)4s - (3F)4p	a2F2.5 - z2F2.5
12	3759.300	26593.14	3.17	(3F)4s - (3F)4p	a2F3.5 - z2F3.5
11	3757.696	26604.49	4.56	d3 - (1D)4p	b2D1.5 - z2P1.5
8	3748.025	26673.14	3.26	d3 - (1G)4p	b2F2.5 - x2F2.5
0	3744.150	26700.74	0.67	(3P)4p - (3F)4d	z4P1.5 - f4F1.5
11	3741.644	26718.62	8.69	d3 - (1D)4p	b2D2.5 - y2D2.5
1	3739.588	26733.31	3.22	d3 - (1G)4p	b2F3.5 - x2F2.5
1	3724.098	26844.50	4.64	d3 - (1D)4p	b2D2.5 - y2D1.5
1	3723.602	26848.08	8.08	d3 - (1D)4p	b2D1.5 - y2D2.5
9	3721.641	26862.23	2.24	(3F)4s - (3F)4p	a2F2.5 - z2F3.5
10	3706.226	26973.95	4.02	d3 - (1D)4p	b2D1.5 - y2D1.5
0	3696.370	27045.87	5.94	d3 - (1D)4p	b2D1.5 - z2P0.5
1	3695.129	27054.96	4.95	d3 - sp(3P)	d2D2.5 - 2P1.5
17	3685.205	27127.81	7.93	(3F)4s - (3F)4p	a2F2.5 - z2D1.5

17	3685.205	27127.81	7.83	(3F)4s - (3F)4p	a2F3.5 - z2D2.5
4	3679.680	27168.54	8.54	d3 - (1D)4p	b2D2.5 - y2F2.5
1	3663.602	27287.77	7.73	(1D)4p - (3F)4d	z2P1.5 - 2P0.5
10	3662.236	27297.95	7.93	d3 - (1D)4p	b2D1.5 - y2F2.5
7	3659.749	27316.49	6.41	d3 - (1D)4p	b2D2.5 - y2F3.5
0	3648.811	27398.38	8.39	d3 - (3P)4p	b2D1.5 - z4S1.5
12	3641.325	27454.71	4.67	d3 - (3P)4p	a2P1.5 - z2S0.5
1	3627.701	27557.81	7.86	(3P)4s - (3P)4p	b4P0.5 - z2S0.5
9	3624.824	27579.68	9.68	d3 - (3P)4p	a2P0.5 - z2S0.5
0	3615.317	27652.21	2.20	(1S)4s - sp(3P)	a2S0.5 - 2P0.5
1	3596.516	27796.75	6.87	d3 - (3P)4p	b2D1.5 - y4D1.5
10	3596.043	27800.41	0.34	(3F)4s - (3F)4p	a2F3.5 - z4D2.5
2	3593.075	27823.37	3.38	d3 - (3P)4p	b2D2.5 - y4D2.5
5	3587.125	27869.53	9.43	(3F)4s - (3F)4p	a2F3.5 - z4D3.5
6	3573.718	27974.07	3.97	(3F)4s - (3F)4p	a2F2.5 - z4D1.5
4	3565.955	28034.97	4.88	d3 - (3P)4p	a4P1.5 - z2S0.5
3	3565.295	28040.16	0.19	d3 - (3P)4p	b2D2.5 - y4D3.5
2	3561.895	28066.92	6.97	d3 - (3P)4p	a4P0.5 - z2S0.5
2	3561.565	28069.52	9.41	(3F)4s - (3F)4p	a2F2.5 - z4D2.5
0	3552.833	28138.51	8.49	(3F)4s - (3F)4p	a2F2.5 - z4D3.5
12	3535.408	28277.20	7.17	(3P)4s - (3P)4p	b2P1.5 - x2D2.5
1	3534.289	28286.15	6.14	(3P)4p - (3F)4d	y4D3.5 - f4F4.5
4	3533.850	28289.66	9.59	(3P)4s - (3P)4p	b2P1.5 - x2D1.5
0	3524.840	28361.97	1.97	s2 - sp(3P)	c2D2.5 - w2D2.5
0	3523.789	28370.43	0.49	(3P)4p - (3F)4d	y4D2.5 - f4F3.5
8	3520.273	28398.77	8.85	(3P)4s - (3P)4p	b2P0.5 - x2D1.5
1	3519.152	28407.81	7.88	(1D)4p - (3F)4d	y2F3.5 - 2D2.5
0	3517.528	28420.93	0.93	(3P)4p - (3F)4d	y4D1.5 - f4F2.5
0	3515.459	28437.66	7.73	(1D)4p - (3F)4d	y2F2.5 - 2D1.5
0	3515.285	28439.06	9.03	(3P)4p - (3F)4d	y4D0.5 - f4F1.5
11	3510.862	28474.89	5.03	(1G)4s - (1G)4p	b2G3.5 - y2G3.5
7	3509.810	28483.42	3.22	(1G)4s - (1G)4p	b2G4.5 - y2G3.5
3	3505.905	28515.15	5.17	(1G)4s - (1G)4p	b2G3.5 - y2G4.5
11	3504.900	28523.32	3.36	(1G)4s - (1G)4p	b2G4.5 - y2G4.5
4	3500.344	28560.45	0.48	d3 - (3F)4p	b4F2.5 - z4G2.5
5	3492.366	28625.69	5.76	(3F)4p - (3F)5s	z2G3.5 - e2F2.5
7	3491.072	28636.30	6.35	d3 - (3F)4p	b4F1.5 - z4G2.5
7	3491.072	28636.30	6.07	s2 - sp(3P)	c2D1.5 - w2D1.5
4	3489.747	28647.17	7.22	d3 - (3F)4p	b4F3.5 - z4G3.5
0	3484.572	28689.72	9.73	(1D)4p - (3F)4d	z2P0.5 - 2D1.5
6	3483.625	28697.51	7.48	(3F)4p - (3F)5s	z2G4.5 - e2F3.5
4	3480.885	28720.10	0.14	(1D)4s - (3P)4p	a2D1.5 - z2S0.5
8	3477.187	28750.64	0.65	d3 - (3F)4p	b4F2.5 - z4G3.5
2	3476.948	28752.62	2.46	d3 - (3F)4p	b4F4.5 - z4G4.5
6	3465.560	28847.10	7.16	(3P)4s - (3P)4p	b2P1.5 - y2P0.5
11	3461.507	28880.88	0.98	d3 - (3F)4p	b4F3.5 - z4G4.5
0	3460.700	28887.61	7.59	(1D)4p - (3F)4d	y2D2.5 - 2D1.5
0	3458.905	28902.60	2.62	(3F)4p - (3F)5s	z2G3.5 - e2F3.5
11	3456.400	28923.55	3.64	(3P)4s - (3P)4p	b2P1.5 - y2P1.5
8	3452.487	28956.33	6.42	(3P)4s - (3P)4p	b2P0.5 - y2P0.5
10	3444.322	29024.97	5.04	d3 - (3F)4p	b4F4.5 - z4G5.5
3	3443.388	29032.85	2.90	(3P)4s - (3P)4p	b2P0.5 - y2P1.5
1	3422.654	29208.72	8.55	(3P)4s - (1D)4p	b4P2.5 - z2P1.5
5	3416.952	29257.45	7.36	d3 - (1D)4p	a2P1.5 - z2P1.5
6	3409.823	29318.62	8.64	(3F)4s - (3F)4p	a4F3.5 - z4G2.5
5	3407.222	29341.00	1.10	(3F)4s - (3F)4p	a4F4.5 - z4G3.5

1	3404.964	29360.46	0.56	(3P)4s - (1D)4p	b4P0.5 - z2P1.5
7	3402.436	29382.28	2.38	d3 - (1D)4p	a2P0.5 - z2P1.5
17	3394.578	29450.29	0.27	(3F)4s - (3F)4p	a4F2.5 - z4G2.5
6	3388.766	29500.80	0.88	d3 - (1D)4p	a2P1.5 - y2D2.5
10	3387.840	29508.86	8.80	(3F)4s - (3F)4p	a4F3.5 - z4G3.5
13	3383.769	29544.36	4.37	(3F)4s - (3F)4p	a4F1.5 - z4G2.5
4	3383.583	29545.99	6.11	(3P)4s - (1D)4p	b4P1.5 - y2D2.5
12	3380.277	29574.88	4.86	(3F)4s - (3F)4p	a4F4.5 - z4G4.5
4	3379.926	29577.95	8.02	(3P)4s - (1D)4p	b4P2.5 - y2D1.5
5	3374.355	29626.78	6.83	d3 - (1D)4p	a2P1.5 - y2D1.5
12	3372.798	29640.46	0.43	(3F)4s - (3F)4p	a4F2.5 - z4G3.5
6	3372.220	29645.54	5.61	(3F)4s - (3F)4p	a2F3.5 - z2G3.5
2	3371.928	29648.11	7.95	(3F)4p - (3F)5s	z4D0.5 - e4F1.5
2	3369.468	29669.75	9.61	(3F)4p - (3F)5s	z4D1.5 - e4F2.5
3	3369.193	29672.17	2.06	(3P)4s - (1D)4p	b4P1.5 - y2D1.5
6blI	3366.190	29698.64	8.75	d3 - (1D)4p	a2P1.5 - z2P0.5
4	3364.582	29712.83	2.79	(3F)4p - (3F)5s	z4D2.5 - e4F3.5
2	3362.638	29730.01	0.02	(3P)4s - (1D)4p	b4P0.5 - y2D1.5
11blI	3361.227	29742.49	2.56	(3F)4s - (3F)4p	a4F3.5 - z4G4.5
4	3352.073	29823.72	3.76	d3 - (1D)4p	a2P0.5 - z2P0.5
5	3351.607	29827.86	7.95	(3F)4p - (3F)5s	z4D3.5 - e4F4.5
1blI	3350.515	29837.58	7.58	d3 - (1D)4p	a4P1.5 - z2P1.5
12	3349.405	29847.47	7.44	(3F)4s - (3F)4p	a4F4.5 - z4G5.5
11	3349.029	29850.82	0.75	(3F)4s - (3F)4p	a2F3.5 - z2G4.5
5	3348.837	29852.53	2.43	d3 - (3F)4p	b4F2.5 - z4F1.5
7	3346.745	29871.19	1.19	d3 - (3F)4p	b4F3.5 - z4F2.5
7	3343.770	29897.76	7.81	d3 - (3F)4p	b4F4.5 - z4F3.5
13blI	3341.858	29914.87	4.68	(3F)4s - (3F)4p	a2F2.5 - z2G3.5
12	3340.341	29928.46	8.30	d3 - (3F)4p	b4F1.5 - z4F1.5
4	3337.851	29950.78	0.74	d3 - (1D)4p	a2P1.5 - y2F2.5
1	3336.942	29958.95	8.75	d3 - (1D)4p	a4P2.5 - y2D2.5
10	3335.182	29974.75	4.62	d3 - (3F)4p	b4F2.5 - z4F2.5
0	3332.812	29996.06	5.97	(3P)4s - (1D)4p	b4P1.5 - y2F2.5
10	3332.112	30002.37	2.38	(3P)4s - (3P)4p	b4P2.5 - z4S1.5
12	3329.458	30026.28	6.33	d3 - (3F)4p	b4F3.5 - z4F3.5
11	3326.765	30050.59	0.48	d3 - (3F)4p	b4F1.5 - z4F2.5
1	3323.382	30081.18	1.10	d3 - (1D)4p	a4P1.5 - y2D2.5
12	3322.939	30085.19	5.17	d3 - (3F)4p	b4F4.5 - z4F4.5
11	3321.697	30096.44	6.42	(3P)4s - (3P)4p	b4P1.5 - z4S1.5
1	3319.074	30120.22	0.11	d3 - (3F)4p	b4F3.5 - z2F2.5
8	3318.021	30129.78	9.77	d3 - (3F)4p	b4F2.5 - z4F3.5
10	3315.320	30154.32	4.39	(3P)4s - (3P)4p	b4P0.5 - z4S1.5
0	3312.921	30176.16	6.21	d3 - (3P)4p	a2P0.5 - z4S1.5
7	3308.800	30213.74	3.69	d3 - (3F)4p	b4F3.5 - z4F4.5
2	3307.720	30223.61	3.54	d3 - (3F)4p	b4F2.5 - z2F2.5
0	3306.024	30239.11	9.13	d3 - (1D)4p	a4P0.5 - y2D1.5
3	3302.099	30275.05	4.98	d3 - (3F)4p	b4F4.5 - z2F3.5
3	3301.664	30279.04	8.96	d3 - (1D)4p	a4P1.5 - z2P0.5
0	3298.175	30311.07	1.05	d3 - (1D)4p	a4P0.5 - z2P0.5
0	3290.114	30385.33	5.31	(3F)4p - (3F)5s	z2D2.5 - e4F3.5
6	3288.581	30399.50	9.47	(3P)4s - (3P)4p	b4P1.5 - y4D0.5
5	3288.425	30400.94	0.86	(3P)4s - (3P)4p	b4P2.5 - y4D1.5
5	3288.136	30403.61	3.50	d3 - (3F)4p	b4F3.5 - z2F3.5
11	3287.657	30408.04	8.00	(1G)4s - (1G)4p	b2G3.5 - z2H4.5
3	3286.771	30416.23	6.20	(1G)4s - (1G)4p	b2G4.5 - z2H4.5
0	3285.939	30423.94	3.64	(3F)4p - (3F)5s	z2D1.5 - e4F1.5

12	3282.323	30457.45	7.43	(3P)4s - (3P)4p	b4P0.5 - y4D0.5
4	3279.983	30479.18	9.26	d3 - (3P)4p	a2P0.5 - y4D0.5
10blI	3278.910	30489.15	9.03	(1D)4s - (1D)4p	a2D2.5 - z2P1.5
10	3278.283	30494.99	4.90	(3P)4s - (3P)4p	b4P1.5 - y4D1.5
2	3276.982	30507.09	6.93	d3 - (3F)4p	b4F2.5 - z2F3.5
7	3276.767	30509.09	9.06	d3 - (3P)4p	a4P2.5 - z4S1.5
4	3275.279	30522.96	2.84	(1D)4s - (1D)4p	a2D1.5 - z2P1.5
2	3274.395	30531.20	0.95	d3 - (1D)4p	a4P1.5 - y2F2.5
10	3272.073	30552.86	2.87	(3P)4s - (3P)4p	b4P0.5 - y4D1.5
10	3271.641	30556.89	6.76	(3P)4s - (3P)4p	b4P2.5 - y4D2.5
7	3263.692	30631.32	1.41	d3 - (3P)4p	a4P1.5 - z4S1.5
12	3261.585	30651.10	0.80	(3P)4s - (3P)4p	b4P1.5 - y4D2.5
12	3261.585	30651.10	1.10	(1G)4s - (1G)4p	b2G4.5 - z2H5.5
5	3260.249	30663.67	3.50	d3 - (3P)4p	a4P0.5 - z4S1.5
1	3255.128	30711.90	1.61	(3F)4p - (3F)4d	z2G4.5 - f2F3.5
9	3254.251	30720.18	0.21	(3F)4s - (3F)4p	a4F4.5 - z4F3.5
10	3252.916	30732.79	2.77	(3F)4s - (3F)4p	a4F3.5 - z4F2.5
10	3252.916	30732.79	2.55	(1D)4s - (1D)4p	a2D2.5 - y2D2.5
10	3251.909	30742.30	2.21	(3F)4s - (3F)4p	a4F2.5 - z4F1.5
1	3251.330	30747.78	7.89	(3F)4p - (3F)5s	z4D2.5 - e2F3.5
3	3249.368	30766.34	6.36	(1D)4s - (1D)4p	a2D1.5 - y2D2.5
12blI	3248.605	30773.56	3.57	(3P)4s - (3P)4p	b4P2.5 - y4D3.5
12	3241.994	30836.32	6.32	(3F)4s - (3F)4p	a4F1.5 - z4F1.5
0	3240.094	30854.40	4.31	(3F)4p - (3F)4d	z2G3.5 - e4D2.5
7	3239.656	30858.57	8.50	(1D)4s - (1D)4p	a2D2.5 - y2D1.5
10	3239.038	30864.45	4.40	(3F)4s - (3F)4p	a4F2.5 - z4F2.5
11	3236.581	30887.89	7.92	(3F)4s - (3F)4p	a4F3.5 - z4F3.5
7	3236.127	30892.22	2.31	(1D)4s - (1D)4p	a2D1.5 - y2D1.5
12	3234.513	30907.64	7.57	(3F)4s - (3F)4p	a4F4.5 - z4F4.5
12	3234.513	30907.64	7.54	d3 - (3P)4p	a4P2.5 - y4D1.5
10	3232.291	30928.88	8.95	d3 - (1D)4p	a2G3.5 - y2F2.5
6	3231.308	30938.29	8.16	d3 - (3F)4p	b4F3.5 - z2D2.5
10	3229.430	30956.28	6.26	d3 - (1D)4p	a2G4.5 - y2F3.5
14	3229.194	30958.54	8.50	(3F)4s - (3F)4p	a4F1.5 - z4F2.5
10	3228.618	30964.07	4.23	(1D)4s - (1D)4p	a2D1.5 - z2P0.5
5	3226.774	30981.76	1.69	(3F)4s - (3F)4p	a4F3.5 - z2F2.5
1	3224.751	31001.19	1.28	d3 - (1S)4p	d2D1.5 - u2P0.5
10	3224.248	31006.03	6.10	d3 - (1G)4p	a2H5.5 - y2G4.5
12	3222.839	31019.59	9.55	(3F)4s - (3F)4p	a4F2.5 - z4F3.5
2	3220.479	31042.32	2.35	d3 - (1S)4p	d2D2.5 - u2P1.5
10	3218.267	31063.65	3.44	d3 - (3P)4p	a4P2.5 - y4D2.5
10	3218.267	31063.65	3.68	d3 - (1G)4p	a2H4.5 - y2G3.5
10	3217.073	31075.18	5.28	(3F)4s - (3F)4p	a4F3.5 - z4F4.5
5	3214.775	31097.40	7.37	(3F)4s - (3F)4p	a4F4.5 - z2F3.5
1	3214.116	31103.77	3.82	d3 - (1G)4p	a2H4.5 - y2G4.5
1blI	3213.489	31109.83	9.77	(3F)4p - (3F)5s	z4F4.5 - e4F3.5
4	3213.147	31113.15	3.32	(3F)4s - (3F)4p	a4F2.5 - z2F2.5
3	3208.471	31158.49	8.51	(3F)4p - (3F)5s	z4F3.5 - e4F2.5
2	3206.005	31182.46	2.41	(1D)4s - (1D)4p	a2D2.5 - y2F2.5
6	3203.427	31207.54	7.43	(3F)4s - (3F)4p	a4F1.5 - z2F2.5
14	3202.559	31216.00	6.22	(1D)4s - (1D)4p	a2D1.5 - y2F2.5
6	3197.526	31265.14	5.08	(3F)4s - (3F)4p	a4F3.5 - z2F3.5
6	3195.712	31282.88	2.86	(1D)4s - (3P)4p	a2D2.5 - z4S1.5
7	3194.575	31294.02	4.01	(3F)4p - (3F)5s	z4F4.5 - e4F4.5
6	3194.260	31297.11	7.13	(3F)4p - (3F)5s	z4F3.5 - e4F3.5
5	3192.557	31313.80	3.66	(3F)4p - (3F)5s	z4F2.5 - e4F2.5

14	3190.914	31329.92	0.27	(1D)4s - (1D)4p	a2D2.5 - y2F3.5
5	3189.489	31343.92	3.84	(3F)4p - (3F)5s	z4F1.5 - e4F1.5
4	3184.120	31396.76	6.71	(3F)4s - (3F)4p	a4F2.5 - z2F3.5
5	3182.537	31412.39	2.50	(3F)4p - (3F)5s	z2D1.5 - e2F2.5
6	3181.726	31420.40	0.41	(3F)4p - (3F)5s	z2D2.5 - e2F3.5
4	3180.152	31435.94	5.84	(3F)4p - (3F)5s	z4F1.5 - e4F2.5
5	3178.504	31452.24	2.28	(3F)4p - (3F)5s	z4F2.5 - e4F3.5
4	3175.567	31481.33	1.37	(3F)4p - (3F)5s	z4F3.5 - e4F4.5
6	3174.799	31488.94	8.85	(1S)4s - (1S)4p	a2S0.5 - u2P0.5
14	3168.550	31551.04	1.23	d3 - (3F)4p	b4F4.5 - z4D3.5
4	3165.283	31583.61	3.78	d3 - (3P)4p	a2G3.5 - y4D2.5
6	3164.905	31587.37	7.33	(1S)4s - (1S)4p	a2S0.5 - u2P1.5
12	3162.586	31610.54	0.67	d3 - (3F)4p	b4F3.5 - z4D2.5
11	3161.798	31618.42	8.66	d3 - (3F)4p	b4F2.5 - z4D1.5
10	3161.231	31624.09	4.19	d3 - (3F)4p	b4F1.5 - z4D0.5
5	3157.401	31662.45	2.41	(3F)4s - (3F)4p	a4F2.5 - z2D1.5
10	3155.681	31679.70	9.37	d3 - (3F)4p	b4F3.5 - z4D3.5
9	3154.217	31694.41	4.53	d3 - (3F)4p	b4F1.5 - z4D1.5
10	3152.268	31714.00	4.11	d3 - (3F)4p	b4F2.5 - z4D2.5
10	3148.063	31756.37	6.51	(3F)4s - (3F)4p	a4F1.5 - z2D1.5
4	3145.423	31783.02	3.19	d3 - (3F)4p	b4F2.5 - z4D3.5
5	3144.738	31789.94	9.97	d3 - (3F)4p	b4F1.5 - z4D2.5
10	3143.773	31799.70	9.74	(3F)4s - (3F)4p	a4F3.5 - z2D2.5
10blI	3130.823	31931.23	1.37	(3F)4s - (3F)4p	a4F2.5 - z2D2.5
6	3128.495	31954.99	5.06	(3F)4p - (3F)5s	z2F3.5 - e2F3.5
6	3127.857	31961.50	1.59	(3F)4p - (3F)5s	z2F2.5 - e2F2.5
5	3122.074	32020.71	0.65	d3 - (3P)4p	a2P1.5 - z4P0.5
5	3121.616	32025.40	5.47	(3F)4s - (3F)4p	a4F1.5 - z2D2.5
14	3119.834	32043.70	3.79	(3P)4s - (3P)4p	b4P2.5 - z4P1.5
4	3118.832	32053.98	4.05	(1D)4s - (3P)4p	a2D2.5 - y4D3.5
10	3117.673	32065.90	5.88	(3P)4s - (3P)4p	b4P1.5 - z4P0.5
4	3115.084	32092.55	2.60	d3 - (3P)4p	a2P1.5 - z4P1.5
7	3112.065	32123.69	3.84	(3P)4s - (3P)4p	b4P0.5 - z4P0.5
7	3110.689	32137.89	7.83	(3P)4s - (3P)4p	b4P1.5 - z4P1.5
6	3110.101	32143.97	4.18	d3 - (3P)4p	b2D2.5 - x2D2.5
7	3108.918	32156.21	6.59	d3 - (3P)4p	b2D2.5 - x2D1.5
12	3106.261	32183.70	3.87	(3P)4s - (3P)4p	b4P2.5 - z4P2.5
10	3105.100	32195.73	5.79	(3P)4s - (3P)4p	b4P0.5 - z4P1.5
6	3104.603	32200.89	0.92	(1G)4s - (1G)4p	b2G3.5 - x2F3.5
13	3103.811	32209.11	9.11	(1G)4s - (1G)4p	b2G4.5 - x2F3.5
6	3102.978	32217.76	7.62	d3 - (3P)4p	a2P0.5 - z4P1.5
6	3101.541	32232.67	2.68	d3 - (3P)4p	a2P1.5 - z4P2.5
1	3097.620	32273.48	3.56	d3 - (3P)4p	b2D1.5 - x2D2.5
10	3097.198	32277.88	7.91	(3P)4s - (3P)4p	b4P1.5 - z4P2.5
5	3096.417	32286.01	5.98	d3 - (3P)4p	b2D1.5 - x2D1.5
7	3089.898	32354.13	4.15	(3F)4p - (3F)5s	z4G5.5 - e4F4.5
12	3089.439	32358.94	9.26	(1G)4s - (1G)4p	b2G3.5 - x2F2.5
10	3081.515	32442.14	2.49	(3F)4p - (3F)5s	z4G4.5 - e4F3.5
15	3078.651	32472.32	2.26	(3F)4s - (3F)4p	a4F3.5 - z4D2.5
1	3077.164	32488.02	7.37	(3F)4p - (3F)5s	z4F2.5 - e2F3.5
13	3075.231	32508.43	8.45	(3F)4s - (3F)4p	a4F2.5 - z4D1.5
12	3072.986	32532.19	2.21	(3F)4s - (3F)4p	a4F1.5 - z4D0.5
6	3072.455	32537.81	7.62	(3F)4p - (3F)5s	z4G3.5 - e4F2.5
12	3072.117	32541.38	1.34	(3F)4s - (3F)4p	a4F3.5 - z4D3.5
9	3071.251	32550.56	0.46	d3 - (3P)4p	a4P2.5 - z4P1.5
5	3068.795	32576.61	6.61	(3F)4p - (3F)4d	z4D2.5 - e4D1.5

12	3066.512	32600.87	0.86	d3 - (3P)4p	a4P1.5 - z4P0.5
18	3066.341	32602.68	2.55	(3F)4s - (3F)4p	a4F1.5 - z4D1.5
14	3066.229	32603.87	3.89	(3F)4s - (3F)4p	a4F2.5 - z4D2.5
14	3066.229	32603.87	3.14	d3 - sp(3P)	b2F2.5 - w2D2.5
4	3065.512	32611.50	1.26	(3F)4p - (3F)4d	z4D1.5 - e4D0.5
5	3065.062	32616.28	6.28	(3F)4p - (3F)4d	z4D2.5 - f2F2.5
3	3064.065	32626.89	6.73	(3F)4p - (3F)5s	z4G4.5 - e4F4.5
4	3063.712	32630.65	0.49	(3F)4p - (3F)4d	z4D3.5 - e4D2.5
6	3063.488	32633.04	2.95	d3 - (3P)4p	a4P0.5 - z4P0.5
6	3063.217	32635.93	5.79	(3F)4p - (3F)5s	z4G2.5 - e4F1.5
3	3060.670	32663.09	3.10	d3 - sp(3P)	b2F3.5 - w2D2.5
8	3059.747	32672.94	2.97	(3F)4s - (3F)4p	a4F2.5 - z4D3.5
8	3059.747	32672.94	2.81	d3 - (3P)4p	a4P1.5 - z4P1.5
4	3059.448	32676.13	6.25	(3F)4p - (3F)5s	z4G3.5 - e4F3.5
4	3058.940	32681.55	1.60	(3F)4p - (3F)4d	z4D0.5 - e4D0.5
10	3058.082	32690.72	0.54	d3 - (3P)4p	a4P2.5 - z4P2.5
7	3057.898	32692.69	2.94	(3F)4p - (3F)4d	z4D3.5 - f2F3.5
7	3057.398	32698.03	7.99	(3F)4s - (3F)4p	a4F1.5 - z4D2.5
6	3057.265	32699.46	9.58	(3F)4p - (3F)4d	z4D2.5 - e4D2.5
9	3056.751	32704.96	4.90	d3 - (3P)4p	a4P0.5 - z4P1.5
7	3054.641	32727.56	7.79	(3F)4p - (3F)5s	z4G2.5 - e4F2.5
5	3053.260	32742.35	2.39	(3F)4p - (3F)4d	z4D0.5 - e4D1.5
7	3051.408	32762.23	2.02	(3F)4p - (3F)4d	z4D2.5 - f2F3.5
7	3048.770	32790.57	0.64	d3 - (3P)4p	b2D2.5 - y2P1.5
5	3048.356	32795.03	5.02	(3F)4p - (3F)4d	z4D1.5 - e4D2.5
9	3046.694	32812.91	2.89	d3 - (3P)4p	a4P1.5 - z4P2.5
7	3044.945	32831.76	1.66	(3F)4p - (3F)4d	z4D3.5 - e4D3.5
6	3043.862	32843.44	3.55	d3 - (3P)4p	b2D1.5 - y2P0.5
6blI	3042.549	32857.61	7.65	(3F)4p - (3F)4d	z2G4.5 - e2G3.5
5	3038.733	32898.88	8.93	d3 - (1G)4p	a2H5.5 - z2H4.5
5	3038.568	32900.65	0.74	(3F)4p - (3F)4d	z4D2.5 - e4D3.5
4	3036.771	32920.12	0.03	d3 - (3P)4p	b2D1.5 - y2P1.5
17	3029.761	32996.30	6.66	d3 - (1G)4p	a2H4.5 - z2H4.5
6	3023.672	33062.74	2.78	(3F)4p - (3F)4d	z2G3.5 - e2G3.5
7	3022.639	33074.03	4.09	(3F)4p - (3F)4d	z2G4.5 - e2G4.5
12	3017.169	33134.00	3.84	d3 - (1G)4p	a2H5.5 - z2H5.5
5	3008.314	33231.52	1.56	d3 - (1G)4p	a2H4.5 - z2H5.5
4	2995.643	33372.08	2.09	(3F)4p - (3F)4d	z2D2.5 - e4D2.5
7blI	2990.055	33434.44	4.54	(3F)4p - (3F)4d	z2D2.5 - f2F3.5
3	2987.380	33464.38	4.35	(1D)4s - (3P)4p	a2D2.5 - z4P2.5
0	2982.596	33518.05	8.09	(3F)4p - (3F)4d	z2D1.5 - e4D1.5
0	2981.311	33532.50	2.56	d3 - (3F)4p	b4F4.5 - z2G4.5
7	2979.061	33557.83	7.76	(3F)4p - (3F)4d	z2D1.5 - f2F2.5
5	2977.686	33573.32	3.26	(3F)4p - (3F)4d	z2D2.5 - e4D3.5
3	2976.875	33582.47	2.62	(3F)4p - (3F)4d	z2G4.5 - e2H4.5
4	2971.676	33641.22	1.06	(3F)4p - (3F)4d	z2D1.5 - e4D2.5
12	2958.802	33787.59	7.76	(3F)4p - (3F)4d	z2G3.5 - e2H4.5
8	2958.174	33794.77	4.79	(3F)4p - (3F)4d	z4F4.5 - e4G4.5
16	2956.166	33817.72	7.48	(3F)4p - (3F)4d	z2F3.5 - e4H4.5
17	2954.591	33835.74	5.88	(3F)4p - (3F)4d	z2G4.5 - e2H5.5
8	2951.995	33865.50	5.49	(3F)4p - (3F)4d	z4F3.5 - e4G3.5
8	2946.552	33928.06	7.98	(3F)4p - (3F)4d	z4F2.5 - e4G2.5
12	2945.298	33942.49	2.45	(3F)4p - (3F)4d	z4F4.5 - e4G5.5
11	2942.972	33969.32	9.20	(3F)4p - (3F)4d	z2F3.5 - f2F3.5
12	2941.899	33981.72	2.15	(3F)4p - (3F)4d	z4F3.5 - e4G4.5
8	2941.262	33989.07	8.81	(3F)4p - (3F)4d	z4D0.5 - 2P0.5

13	2938.567	34020.24	0.64	(3F)4p - (3F)4d	z4F2.5 - e4G3.5
13	2936.021	34049.75	0.17	(3F)4p - (3F)4d	z4F1.5 - e4G2.5
14	2931.103	34106.87	6.85	(3F)4p - (3F)4d	z2F2.5 - f2F2.5
14	2931.039	34107.61	7.92	(3F)4p - (3F)4d	z2F3.5 - e4D3.5
8	2927.801	34145.34	5.25	(3F)4p - (3F)4d	z4F4.5 - e4H5.5
11	2926.644	34158.84	9.00	(3F)4p - (3F)4d	z4F4.5 - f2F3.5
9	2923.969	34190.09	0.14	(3F)4p - (3F)4d	z2F2.5 - e4D2.5
8	2923.577	34194.66	4.64	(3F)4p - (3F)4d	z4F3.5 - e4H4.5
8	2923.577	34194.66	4.89	s2 - sp(3P)	c2D2.5 - 2P1.5
8	2923.060	34200.72	0.62	(3F)4p - (3F)4d	z4F3.5 - f2F2.5
8	2918.628	34252.64	2.59	(3F)4p - (3F)4d	z2F2.5 - f2F3.5
7	2916.697	34275.33	5.22	s2 - sp(3P)	c2D2.5 - w2F3.5
10	2915.976	34283.80	3.91	(3F)4p - (3F)4d	z4F3.5 - e4D2.5
9	2914.807	34297.55	7.72	(3F)4p - (3F)4d	z4F4.5 - e4D3.5
11	2913.236	34316.04	6.10	(3F)4p - (3F)4d	z4F2.5 - e4D1.5
7	2910.647	34346.57	6.36	(3F)4p - (3F)4d	z4F3.5 - f2F3.5
10	2909.962	34354.65	4.96	(3F)4s - (3F)4p	a4F4.5 - z2G4.5
7	2909.371	34361.63	1.62	s2 - sp(3P)	c2D1.5 - w2F2.5
9	2908.017	34377.62	7.49	(3F)4p - (3F)4d	z4F1.5 - e4D0.5
8	2906.862	34391.28	1.31	(3F)4p - (3F)4d	z2F2.5 - e4D3.5
9	2902.870	34438.58	8.28	(3F)4p - (3F)4d	z4F1.5 - e4D1.5
9	2902.826	34439.06	9.09	(3F)4p - (3F)4d	z4F2.5 - e4D2.5
7	2901.957	34449.41	9.16	(3F)4s - (3F)4p	a4F2.5 - z2G3.5
7	2895.794	34522.72	2.67	(3F)4s - (3F)4p	a4F3.5 - z2G4.5
15	2891.082	34578.99	9.15	(3F)4s - (1D)4p	a2F3.5 - y2D2.5
12	2888.942	34604.60	4.70	(3F)4s - (1D)4p	a2F2.5 - z2P1.5
9	2887.442	34622.58	2.39	d3 - (1G)4p	a2G4.5 - y2G3.5
18	2884.127	34662.37	2.53	d3 - (1G)4p	a2G4.5 - y2G4.5
8	2880.303	34708.38	8.42	d3 - (1G)4p	b2D2.5 - x2F3.5
17	2877.466	34742.61	2.94	d3 - (1G)4p	a2G3.5 - y2G3.5
9	2875.658	34764.45	4.50	(3F)4p - (3F)4d	z2D1.5 - 2P0.5
10	2875.329	34768.43	8.53	(3F)4p - (3F)4d	z2D2.5 - 2P1.5
8	2874.114	34783.12	3.08	d3 - (1G)4p	a2G3.5 - y2G4.5
12	2868.750	34848.16	8.22	(3F)4s - (1D)4p	a2F2.5 - y2D2.5
8	2868.182	34855.05	4.92	(3F)4p - (3F)4d	z4G5.5 - e4G4.5
15	2862.332	34926.29	6.37	d3 - (3P)4p	a2P1.5 - x2D2.5
10	2861.302	34938.86	8.78	d3 - (3P)4p	a2P1.5 - x2D1.5
9	2858.405	34974.27	4.17	(3F)4s - (1D)4p	a2F2.5 - y2D1.5
10	2857.615	34983.94	4.01	(3P)4s - (3P)4p	b4P1.5 - x2D1.5
8	2856.598	34996.39	6.39	(1D)4s - (1G)4p	a2D2.5 - y2G3.5
8	2856.588	34996.52	6.16	d3 - (1G)4p	b2D1.5 - x2F2.5
15	2856.102	35002.47	2.58	(3F)4p - (3F)4d	z4G5.5 - e4G5.5
8	2855.400	35011.08	0.85	(3F)4p - (3F)4d	z4G4.5 - e4G3.5
12	2853.932	35029.09	9.01	(3F)4s - (1D)4p	a2F3.5 - y2F2.5
9	2853.238	35037.61	7.50	(3F)4p - (3F)4d	z2D1.5 - 2P1.5
7	2852.882	35041.98	1.98	(3P)4s - (3P)4p	b4P0.5 - x2D1.5
7	2851.791	35055.38	5.42	(3F)4p - (3F)4d	z4D3.5 - e2G4.5
15	2851.109	35063.76	3.80	d3 - (3P)4p	a2P0.5 - x2D1.5
12	2845.931	35127.56	7.51	(3F)4p - (3F)4d	z4G4.5 - e4G4.5
8	2843.937	35152.19	1.95	(3F)4p - (3F)4d	z4G3.5 - e4G2.5
16	2841.942	35176.87	6.87	(3F)4s - (1D)4p	a2F3.5 - y2F3.5
13	2839.635	35205.44	5.39	(3F)4p - (3F)4d	z4G5.5 - e4H5.5
d7	2838.586	35218.45	8.45	(3F)4p - (3F)4d	z4G4.5 - e4H3.5
12	2836.474	35244.68	4.61	(3F)4p - (3F)4d	z4G3.5 - e4G3.5
11	2834.020	35275.19	5.16	(3F)4p - (3F)4d	z4G4.5 - e4G5.5
17	2832.186	35298.04	8.08	(3F)4s - (1D)4p	a2F2.5 - y2F2.5

12	2828.828	35339.94	0.00	(3F)4p - (3F)4d	z4G4.5 - e4H4.5
10	2828.642	35342.25	2.11	(3F)4p - (3F)4d	z4G2.5 - e4G2.5
16	2828.064	35349.47	9.32	(3F)4p - (3F)4d	z4G5.5 - e4H6.5
11	2827.124	35361.23	1.27	(3F)4p - (3F)4d	z4G3.5 - e4G4.5
10	2821.257	35434.77	4.78	(3F)4p - (3F)4d	z4G2.5 - e4G3.5
9	2820.355	35446.09	5.94	(3F)4s - (1D)4p	a2F2.5 - y2F3.5
9	2819.871	35452.17	2.21	(3F)4p - (3F)4d	z4G3.5 - e4H3.5
14	2817.826	35477.91	7.97	(3F)4p - (3F)4d	z4G4.5 - e4H5.5
9	2816.349	35496.51	6.36	d3 - (3P)4p	a2P1.5 - y2P0.5
9	2815.545	35506.65	6.58	d3 - (3P)4p	a4P1.5 - x2D2.5
7	2814.535	35519.39	9.00	d3 - (3P)4p	a4P1.5 - x2D1.5
8	2812.004	35551.36	1.09	d3 - (3P)4p	a4P0.5 - x2D1.5
17	2810.297	35572.95	2.84	(3F)4p - (3F)4d	z4G3.5 - e4H4.5
17	2810.242	35573.64	3.76	d3 - (3P)4p	a2P1.5 - y2P1.5
8	2809.696	35580.56	0.57	(3F)4p - (3F)4d	z2D2.5 - e2G3.5
9	2806.464	35621.54	1.37	d3 - (3P)4p	a2P0.5 - y2P0.5
13	2804.816	35642.46	2.37	(3F)4p - (3F)4d	z4G2.5 - e4H3.5
12	2800.477	35697.68	7.86	d3 - (3P)4p	a2P0.5 - y2P1.5
7	2799.089	35715.38	5.33	(3F)4p - (3F)4d	z4D3.5 - 2D2.5
9	2784.634	35900.77	0.65	(3F)4s - (3P)4p	a2F3.5 - y4D3.5
7	2771.025	36077.07	6.57	d3 - (3P)4p	a4P1.5 - y2P0.5
7	2768.094	36115.28	5.23	(3F)4p - (3F)4d	z2F3.5 - e2G3.5
11	2764.821	36158.03	8.04	(1D)4s - (3P)4p	a2D2.5 - x2D2.5
9	2762.229	36191.95	1.85	(1D)4s - (3P)4p	a2D1.5 - x2D2.5
11	2761.297	36204.17	4.26	(1D)4s - (3P)4p	a2D1.5 - x2D1.5
9	2758.791	36237.06	6.98	(3F)4p - (3F)4d	z4D0.5 - f4F1.5
11	2752.680	36317.49	7.37	(3F)4p - (3F)4d	z4D3.5 - f4F4.5
12	2751.591	36331.87	1.67	(3F)4p - (3F)4d	z2F3.5 - e2G4.5
8	2751.055	36338.95	8.92	(3F)4p - (3F)4d	z2D2.5 - 2D1.5
13	2746.537	36398.73	8.62	(3F)4p - (3F)4d	z2F2.5 - e2G3.5
10	2742.155	36456.88	6.93	(3F)4p - (3F)4d	z2D2.5 - 2D2.5
11	2730.847	36607.84	7.88	(3F)4p - (3F)4d	z2D1.5 - 2D1.5
10	2725.775	36675.96	5.92	d3 - (1G)4p	a2G3.5 - z2H4.5
7	2723.318	36709.04	8.84	(3F)4p - (3F)4d	z4F3.5 - e2G4.5
8	2722.069	36725.89	5.89	(3F)4p - (3F)4d	z2D1.5 - 2D2.5
10	2719.408	36761.82	1.83	(1D)4s - (3P)4p	a2D1.5 - y2P0.5
10	2717.301	36790.32	0.27	d3 - (1G)4p	a2G4.5 - z2H5.5
10	2716.249	36804.57	4.51	(1D)4s - (3P)4p	a2D2.5 - y2P1.5
7	2713.738	36838.62	8.32	(1D)4s - (3P)4p	a2D1.5 - y2P1.5
8	2707.028	36929.92	9.65	(3P)4s - sp(3P)	b2P1.5 - w2D2.5
8	2703.961	36971.81	1.99	(3P)4s - sp(3P)	b2P1.5 - w2D1.5
11	2702.514	36991.62	1.59	(3F)4p - (3F)4d	z2F3.5 - 2D2.5
8	2695.975	37081.33	1.25	(3P)4s - sp(3P)	b2P0.5 - w2D1.5
9	2690.485	37156.98	6.97	(3F)4p - (3F)4d	z2F2.5 - 2D1.5
7	2676.780	37347.23	7.31	d3 - sp(3P)	d2D1.5 - v2D2.5
7	2668.665	37460.79	1.16	(3F)4p - (3F)4d	z2F3.5 - f4F3.5
7	2664.170	37523.98	3.90	(3F)4p - (3F)4d	z4F2.5 - 2D2.5
8	2663.880	37528.07	8.07	(3F)4p - (3F)4d	z4F1.5 - 2D1.5
8	2655.186	37650.94	0.97	(3F)4p - (3F)4d	z4F4.5 - f4F3.5
8	2649.400	37733.15	2.87	(3F)4p - (3F)4d	z4F3.5 - f4F2.5
15	2645.860	37783.64	3.43	(3F)4p - (3F)4d	z4F4.5 - f4F4.5
12	2642.020	37838.55	8.33	(3F)4p - (3F)4d	z4F3.5 - f4F3.5
12	2638.564	37888.11	8.02	(3F)4p - (3F)4d	z4F2.5 - f4F2.5
11	2635.437	37933.06	2.87	(3F)4p - (3F)4d	z4F1.5 - f4F1.5
7	2632.810	37970.91	0.79	(3F)4p - (3F)4d	z4F3.5 - f4F4.5
9	2631.262	37993.24	3.47	(3F)4p - (3F)4d	z4F2.5 - f4F3.5

8	2630.096	38010.09	0.21	(3F)4p - (3F)4d	z4F1.5 - f4F2.5
7	2626.546	38061.46	1.67	(3F)4p - (3F)4d	z4G2.5 - e2G3.5
11	2611.905	38274.81	4.81	d3 - sp(3P)	d2D2.5 - v2F2.5
9	2604.108	38389.40	9.48	d3 - (1D)4p	b4F3.5 - y2D2.5
9	2592.582	38560.06	0.06	d3 - sp(3P)	d2D2.5 - v2F3.5
8	2591.531	38575.70	6.35	d3 - sp(3P)	b2F3.5 - w2F3.5
12	2581.700	38722.58	2.29	(1D)4s - (1G)4p	a2D2.5 - x2F3.5
10	2573.657	38843.59	3.57	(3F)4p - (3F)4d	z4G5.5 - f4F4.5
10	2573.670	38843.38	3.00	(3F)4s - (1G)4p	a2F3.5 - y2G3.5
11	2572.667	38858.52	8.68	d3 - (1D)4p	b4F4.5 - y2F3.5
17	2571.076	38882.58	3.14	(3F)4s - (1G)4p	a2F3.5 - y2G4.5
10	2568.983	38914.24	4.44	(1D)4s - (1G)4p	a2D1.5 - x2F2.5
15	2556.007	39111.79	1.98	(3F)4p - (3F)4d	z4G3.5 - f4F2.5
15	2556.007	39111.79	2.07	(3F)4s - (1G)4p	a2F2.5 - y2G3.5
7	2549.064	39218.32	7.44	(3F)4p - (3F)4d	z4G3.5 - f4F3.5
9	2548.654	39224.62	4.82	(3F)4p - (3F)4d	z4G2.5 - f4F1.5
9	2536.787	39408.11	7.61	(3F)4p - (3F)4d	z4G2.5 - f4F3.5
15	2535.887	39422.08	2.14	d3 - (3P)4p	b4F1.5 - y4D0.5
17	2534.626	39441.69	1.70	d3 - (3P)4p	b4F2.5 - y4D1.5
17	2531.279	39493.85	4.17	d3 - (3P)4p	b4F3.5 - y4D2.5
17	2529.785	39517.16	7.57	d3 - (3P)4p	b4F1.5 - y4D1.5
17	2525.586	39582.86	2.46	d3 - (3P)4p	b4F4.5 - y4D3.5
14	2524.659	39597.40	7.61	d3 - (3P)4p	b4F2.5 - y4D2.5
8	2519.815	39673.51	3.47	d3 - (3P)4p	b4F1.5 - y4D2.5
15	2517.417	39711.30	0.98	d3 - (3P)4p	b4F3.5 - y4D3.5
9	2510.868	39814.87	4.42	d3 - (3P)4p	b4F2.5 - y4D3.5
7	2503.862	39926.28	6.66	(3F)4s - (1D)4p	a4F1.5 - y2F2.5

able II: Observed Ti II lines below 2500 Å.

Int.	λ_{vac}(Å)	σ_{calc}(cm^{-1})	Transition Configurations	Transition Levels
6	2499.710	40004.6	(3F)4s - (3P)4p	a2F3.5 - x2D2.5
2	2483.009	40273.7	(3F)4s - (3P)4p	a2F2.5 - x2D2.5
4	2482.244	40286.1	(3F)4s - (3P)4p	a2F2.5 - x2D1.5
3	2479.534	40330.2	(3F)4s - (3P)4p	a4F1.5 - y4D0.5
3	2479.452	40331.5	(3F)4s - (3P)4p	a4F2.5 - y4D1.5
6	2477.961	40355.8	(3F)4s - (3P)4p	a4F3.5 - y4D2.5
5	2474.950	40404.9	(3F)4s - (3P)4p	a4F4.5 - y4D3.5
4	2473.681	40425.6	(3F)4s - (3P)4p	a4F1.5 - y4D1.5
3	2469.905	40487.4	(3F)4s - (3P)4p	a4F2.5 - y4D2.5
4	2464.719	40572.6	(3F)4s - (3P)4p	a4F3.5 - y4D3.5
0	2464.178	40581.5	(3F)4s - (3P)4p	a4F1.5 - y4D2.5
0	2456.749	40704.2	(3F)4s - (3P)4p	a4F2.5 - y4D3.5
12	2451.182	40796.6	d3 - sp(3P)	b2D2.5 - w2D2.5
4	2448.640	40839.0	d3 - sp(3P)	b2D2.5 - w2D1.5
7	2443.432	40926.0	d3 - sp(3P)	b2D1.5 - w2D2.5
13	2440.907	40968.4	d3 - sp(3P)	b2D1.5 - w2D1.5
3	2427.824	41189.1	d3 - (3F)5p	d2D2.5 - 2F2.5
6	2424.445	41246.6	d3 - (3F)5p	d2D1.5 - 2F2.5
4	2418.234	41352.5	d3 - sp(3P)	d2D1.5 - 2P0.5
6	2411.501	41467.9	d3 - (3F)5p	d2D2.5 - 2F3.5
8	2402.848	41617.3	d3 - sp(3P)	d2D2.5 - 2P1.5
2	2399.538	41674.7	d3 - sp(3P)	d2D1.5 - 2P1.5
3	2390.053	41840.1	(1S)4s - sp(3P)	a2S0.5 - 2P0.5
2	2378.350	42045.9	d3 - (3F)5p	d2D2.5 - 2D1.5
3	2375.108	42103.4	d3 - (3F)5p	d2D1.5 - 2D1.5
2	2374.480	42114.5	(3F)4s - (3P)4p	a4F2.5 - z4P2.5
3	2371.789	42162.3	(1S)4s - sp(3P)	a2S0.5 - 2P1.5
2	2363.753	42305.6	(3P)4s - sp(3P)	b4P2.5 - 4F1.5
4	2363.376	42312.4	d3 - (3F)5p	d2D2.5 - 2D2.5
2	2360.173	42369.8	d3 - (3F)5p	d2D1.5 - 2D2.5
5	2358.510	42399.6	(3P)4s - sp(3P)	b4P1.5 - 4F1.5
4	2358.009	42408.7	(3P)4s - sp(3P)	b4P1.5 - 4D0.5
2	2356.567	42434.6	(3P)4s - sp(3P)	b4P2.5 - 4D1.5
4	2355.857	42447.4	(3P)4s - sp(3P)	b4P2.5 - 4F2.5
3	2355.291	42457.6	(3P)4s - sp(3P)	b4P0.5 - 4F1.5
7	2354.791	42466.6	(3P)4s - sp(3P)	b4P0.5 - 4D0.5
1	2353.581	42488.4	d3 - sp(3P)	a2P0.5 - 4D0.5
0	2353.151	42496.2	d3 - sp(3P)	a2P1.5 - 4F2.5
5	2351.356	42528.6	(3P)4s - sp(3P)	b4P1.5 - 4D1.5
6	2350.650	42541.4	(3P)4s - sp(3P)	b4P1.5 - 4F2.5
3	2349.133	42568.9	(3F)4s - (1G)4p	a2F3.5 - x2F3.5
5	2348.156	42586.6	(3P)4s - sp(3P)	b4P0.5 - 4D1.5
0	2347.918	42590.9	(1S)4s - (3F)5p	a2S0.5 - 2D1.5
4	2347.072	42606.3	(3P)4s - sp(3P)	b4P2.5 - 4D2.5
0	2346.953	42608.4	d3 - sp(3P)	a2P0.5 - 4D1.5
1	2344.387	42655.1	d3 - sp(3P)	a2P1.5 - 4D2.5
11	2342.994	42680.4	(3P)4s - sp(3P)	b4P2.5 - 4F3.5
10	2341.904	42700.3	(3P)4s - sp(3P)	b4P1.5 - 4D2.5
1	2340.428	42727.2	(3F)4s - (1G)4p	a2F3.5 - x2F2.5
2	2338.494	42762.6	(3P)4s - sp(3P)	b2P1.5 - 2P1.5

2	2335.639	42814.8	(3P)4s - sp(3P)	b2P1.5 - 2P0.5
7	2335.252	42821.9	(3P)4s - sp(3P)	b4P2.5 - 4D3.5
2	2334.378	42838.0	(3F)4s - (1G)4p	a2F2.5 - x2F3.5
2	2332.534	42871.8	(3P)4s - sp(3P)	b2P0.5 - 2P1.5
3	2329.694	42924.1	(3P)4s - sp(3P)	b2P0.5 - 2P0.5
1	2329.122	42934.6	d3 - sp(3P)	a4P1.5 - 4F1.5
0	2328.634	42943.6	d3 - sp(3P)	a4P1.5 - 4D0.5
2	2328.068	42954.1	d3 - sp(3P)	a4P2.5 - 4F2.5
0	2327.383	42966.7	d3 - sp(3P)	a4P0.5 - 4F1.5
3	2326.895	42975.7	d3 - sp(3P)	a4P0.5 - 4D0.5
4	2325.781	42996.3	(3F)4s - (1G)4p	a2F2.5 - x2F2.5
1	2322.145	43063.6	d3 - sp(3P)	a4P1.5 - 4D1.5
2	2321.456	43076.4	d3 - sp(3P)	a4P1.5 - 4F2.5
1	2320.416	43095.7	d3 - sp(3P)	a4P0.5 - 4D1.5
0	2319.489	43112.9	d3 - sp(3P)	a4P2.5 - 4D2.5
3	2315.506	43187.1	d3 - sp(3P)	a4P2.5 - 4F3.5
1	2312.925	43235.3	d3 - sp(3P)	a4P1.5 - 4D2.5
0	2308.496	43318.3	(1D)4p - (3F)6s	y2F2.5 - 2F2.5
1	2307.944	43328.6	d3 - sp(3P)	a4P2.5 - 4D3.5
0	2301.780	43444.6	(1D)4p - (3F)6s	y2F3.5 - 2F3.5
3	2297.264	43530.0	(3P)4s - sp(3P)	b4P2.5 - w2D2.5
1	2295.284	43567.6	d3 - sp(3P)	b2D2.5 - y4P2.5
2	2295.032	43572.4	(3P)4s - sp(3P)	b4P2.5 - w2D1.5
2	2294.691	43578.8	d3 - sp(3P)	a2P1.5 - w2D2.5
	2294.310	43586.1	(1D)4s - sp(3P)	a2D2.5 - 4F1.5
1	2294.267	43586.9	d3 - sp(3P)	a2G4.5 - 4F3.5
3	2292.532	43619.9	(1D)4s - sp(3P)	a2D1.5 - 4F1.5
	2292.507	43620.4	d3 - sp(3P)	b2D1.5 - y4P1.5
3	2292.464	43621.2	d3 - sp(3P)	a2P1.5 - w2D1.5
2	2292.312	43624.1	(3P)4s - sp(3P)	b4P1.5 - w2D2.5
0	2292.059	43628.9	(1D)4s - sp(3P)	a2D1.5 - 4D0.5
1	2290.090	43666.4	(3P)4s - sp(3P)	b4P1.5 - w2D1.5
0	2287.053	43724.4	(3P)4s - sp(3P)	b4P0.5 - w2D1.5
4	2286.871	43727.9	(1D)4s - sp(3P)	a2D2.5 - 4F2.5
3	2286.844	43728.4	d3 - sp(3P)	a2G4.5 - 4D3.5
2	2285.913	43746.2	d3 - sp(3P)	a2P0.5 - w2D1.5
0	2285.104	43761.7	(1D)4s - sp(3P)	a2D1.5 - 4F2.5
0	2282.325	43815.0	d3 - (3P)4p	b4F3.5 - x2D2.5
0	2278.592	43886.7	(1D)4s - sp(3P)	a2D2.5 - 4D2.5
3	2276.950	43918.4	d3 - (3P)4p	b4F2.5 - x2D2.5
0	2276.838	43920.6	(1D)4s - sp(3P)	a2D1.5 - 4D2.5
2	2274.748	43960.9	(1D)4s - sp(3P)	a2D2.5 - 4F3.5
13	2269.785	44057.0	(1G)4s - sp(3P)	b2G3.5 - w2F2.5
1	2267.450	44102.4	(1D)4s - sp(3P)	a2D2.5 - 4D3.5
4	2265.789	44134.7	s2 - sp(3P)	c2D2.5 - v2D1.5
4	2262.321	44202.4	(1G)4s - sp(3P)	b2G3.5 - w2F3.5
13	2261.902	44210.6	(1G)4s - sp(3P)	b2G4.5 - w2F3.5
11	2253.953	44366.5	s2 - sp(3P)	c2D1.5 - v2D1.5
12	2250.740	44429.8	s2 - sp(3P)	c2D2.5 - v2D2.5
4	2239.060	44661.6	s2 - sp(3P)	c2D1.5 - v2D2.5
13	2231.619	44810.5	(1D)4s - sp(3P)	a2D2.5 - w2D2.5
8	2229.937	44844.3	(1D)4s - sp(3P)	a2D1.5 - w2D2.5
9	2229.512	44852.9	(1D)4s - sp(3P)	a2D2.5 - w2D1.5
12	2227.833	44886.7	(1D)4s - sp(3P)	a2D1.5 - w2D1.5
3	2201.928	45414.7	s2 - sp(3P)	c2D2.5 - v2F2.5
9	2190.748	45646.5	s2 - sp(3P)	c2D1.5 - v2F2.5

10	2188.184	45700.0	s2 - sp(3P)	c2D2.5 - v2F3.5
9	2163.361	46224.4	(3P)4s - sp(3P)	b4P2.5 - y4P1.5
1	2162.307	46246.9	d3 - sp(3P)	a2P1.5 - y4P0.5
0	2161.079	46273.2	d3 - sp(3P)	a2P1.5 - y4P1.5
8	2160.195	46292.1	(3P)4s - sp(3P)	b4P1.5 - y4P0.5
9	2159.782	46301.0	(3P)4s - sp(3P)	b4P2.5 - y4P2.5
7	2158.969	46318.4	(3P)4s - sp(3P)	b4P1.5 - y4P1.5
	2157.493	46350.1	d3 - sp(3P)	a2P1.5 - y4P2.5
5	2157.493	46350.1	(3P)4s - sp(3P)	b4P0.5 - y4P0.5
0	2156.478	46371.9	d3 - sp(3P)	a2P0.5 - y4P0.5
8	2156.270	46376.4	(3P)4s - sp(3P)	b4P0.5 - y4P1.5
10	2155.404	46395.0	(3P)4s - sp(3P)	b4P1.5 - y4P2.5
2	2155.256	46398.2	d3 - sp(3P)	a2P0.5 - y4P1.5
0	2147.557	46564.5	d3 - sp(3P)	b2D2.5 - w2F2.5
3	2144.562	46629.6	d3 - sp(3P)	b2D2.5 - 2P1.5
3	2143.555	46651.5	(3P)4s - (1S)4p	b2P1.5 - u2P0.5
1	2141.606	46693.9	d3 - sp(3P)	b2D1.5 - w2F2.5
0	2140.874	46709.9	d3 - sp(3P)	b2D2.5 - w2F3.5
3	2139.905	46731.0	d3 - sp(3P)	a4P2.5 - y4P1.5
5	2139.039	46750.0	(3P)4s - (1S)4p	b2P1.5 - u2P1.5
	2138.628	46759.0	d3 - sp(3P)	b2D1.5 - 2P1.5
5	2138.546	46760.7	(3P)4s - (1S)4p	b2P0.5 - u2P0.5
5	2136.403	46807.6	d3 - sp(3P)	a4P2.5 - y4P2.5
2	2136.240	46811.2	d3 - sp(3P)	b2D1.5 - 2P0.5
3	2135.515	46827.1	d3 - sp(3P)	a4P1.5 - y4P0.5
2	2134.317	46853.4	d3 - sp(3P)	a4P1.5 - y4P1.5
	2134.052	46859.2	(3P)4s - (1S)4p	b2P0.5 - u2P1.5
3	2134.052	46859.2	d3 - sp(3P)	a4P0.5 - y4P0.5
3	2132.856	46885.5	d3 - sp(3P)	a4P0.5 - y4P1.5
4	2130.833	46930.0	d3 - sp(3P)	a4P1.5 - y4P2.5
0	2124.356	47073.1	(3F)4s - (1G)4p	a4F4.5 - x2F3.5
0	2116.814	47240.8	(3F)4s - (1G)4p	a4F3.5 - x2F3.5
0	2109.742	47399.2	(3F)4s - (1G)4p	a4F3.5 - x2F2.5
3	2105.048	47504.9	(1D)4s - sp(3P)	a2D2.5 - y4P1.5
0	2104.715	47512.4	(1D)4s - sp(3P)	a2D1.5 - y4P0.5
1	2103.900	47530.8	(3F)4s - (1G)4p	a4F2.5 - x2F2.5
0	2103.551	47538.7	(1D)4s - sp(3P)	a2D1.5 - y4P1.5
1	2101.967	47574.5	(3F)4s - sp(3P)	a2F3.5 - 4F2.5
1	2101.659	47581.5	(1D)4s - sp(3P)	a2D2.5 - y4P2.5
0	2100.167	47615.3	(1D)4s - sp(3P)	a2D1.5 - y4P2.5
0	2099.743	47624.9	(3F)4s - (1G)4p	a4F1.5 - x2F2.5
1	2096.359	47701.7	(3F)4s - sp(3P)	a2F2.5 - 4F1.5
0	2094.971	47733.3	(3F)4s - sp(3P)	a2F3.5 - 4D2.5
0	2091.721	47807.5	(3F)4s - sp(3P)	a2F3.5 - 4F3.5
0	2090.705	47830.8	(3F)4s - sp(3P)	a2F2.5 - 4D1.5
0	2090.146	47843.5	(3F)4s - sp(3P)	a2F2.5 - 4F2.5
0	2083.228	48002.4	(3F)4s - sp(3P)	a2F2.5 - 4D2.5
0	2069.967	48309.9	(3F)4p - (3F)6s	z2G4.5 - 4F3.5
5	2069.148	48329.1	s2 - (3F)5p	c2D2.5 - 2F2.5
0	2067.362	48370.8	(3F)4p - (3F)6s	z2G3.5 - 4F2.5
0	2067.145	48375.9	d3 - sp(3P)	b2F2.5 - v2D1.5
0	2061.488	48508.6	(3F)4p - (3F)6s	z2G4.5 - 4F4.5
0	2061.215	48515.1	(3F)4p - (3F)6s	z2G3.5 - 4F3.5
7	2059.272	48560.8	s2 - (3F)5p	c2D1.5 - 2F2.5
9	2057.280	48607.9	s2 - (3F)5p	c2D2.5 - 2F3.5
8	2055.198	48657.1	(3F)4s - sp(3P)	a2F3.5 - w2D2.5

7	2054.789	48666.8	s2 - sp(3P)	c2D1.5 - 2P0.5
2	2053.318	48701.7	(3F)4p - (3F)6s	z2G3.5 - 2F2.5
2	2052.083	48731.0	d3 - sp(3P)	b2F3.5 - v2D2.5
7	2050.978	48757.2	s2 - sp(3P)	c2D2.5 - 2P1.5
3	2050.409	48770.8	(3F)4p - (3F)6s	z2G4.5 - 2F3.5
4	2043.895	48926.2	(3F)4s - sp(3P)	a2F2.5 - w2D2.5
10	2042.128	48968.5	(3F)4s - sp(3P)	a2F2.5 - w2D1.5
0	2041.821	48975.9	(3F)4p - (3F)6s	z2G3.5 - 2F3.5
5	2041.275	48989.0	s2 - sp(3P)	c2D1.5 - 2P1.5
1	2023.810	49411.8	d3 - sp(3P)	a2P1.5 - 2P1.5
7	2023.569	49417.6	s2 - (3F)5p	c2D1.5 - 2D1.5
10	2022.151	49452.3	s2 - (3F)5p	c2D2.5 - 2D2.5
1	2021.671	49464.0	d3 - sp(3P)	a2P1.5 - 2P0.5
0	2018.702	49536.8	d3 - sp(3P)	a2P0.5 - 2P1.5
0	2013.371	49667.9	d3 - (3F)4f	d2D1.5 - 2F2.5
3	2012.718	49684.1	s2 - (3F)5p	c2D1.5 - 2D2.5
1	2009.302	49768.5	d3 - (3F)4f	d2D1.5 - 4P0.5
0	2008.429	49790.2	d3 - (3F)4f	d2D1.5 - 2D1.5
1	2007.283	49818.6	d3 - (3F)4f	d2D2.5 - 2F3.5
0	2001.140	49971.5	d3 - (3F)4f	d2D2.5 - 4S1.5
1	2000.553	49986.2	d3 - (3F)4f	d2D2.5 - 2D2.5
0	1999.955	50001.1	d3 - sp(3P)	b2F3.5 - v2F3.5
0	1998.843	50028.9	d3 - (3F)4f	d2D1.5 - 4S1.5
0	1998.512	50037.2	d3 - (3F)4f	d2D2.5 - 2P1.5
0	1998.258	50043.6	d3 - (3F)4f	d2D1.5 - 2D2.5
0	1996.221	50094.6	d3 - (3F)4f	d2D1.5 - 2P1.5
0	1991.393	50216.1	(3F)4p - (3F)6s	z4D2.5 - 4F2.5
0	1990.583	50236.5	(3F)4p - (3F)6s	z4D1.5 - 4F1.5
0	1988.417	50291.3	(3F)4p - (3F)6s	z4D3.5 - 4F3.5
2	1987.800	50306.9	(3F)4p - (3F)6s	z4D0.5 - 4F1.5
0	1987.616	50311.5	(3F)4p - (3F)6s	z4D1.5 - 4F2.5
3	1987.086	50324.9	d3 - sp(3P)	a2G3.5 - w2F2.5
4	1986.107	50349.8	d3 - sp(3P)	a2G4.5 - w2F3.5
1	1985.689	50360.3	(3F)4p - (3F)6s	z4D2.5 - 4F3.5
1	1981.363	50470.3	d3 - sp(3P)	a2G3.5 - w2F3.5
2	1980.591	50490.0	(3F)4p - (3F)6s	z4D3.5 - 4F4.5
0	1977.128	50578.4	(1D)4s - sp(3P)	a2D2.5 - w2F2.5
1	1975.808	50612.2	(1D)4s - sp(3P)	a2D1.5 - w2F2.5
6	1975.622	50617.0	d3 - (1S)4p	b2D2.5 - u2P1.5
	1974.631	50642.4	(3F)4p - (3F)6s	z4D1.5 - 2F2.5
8	1974.590	50643.4	(1D)4s - sp(3P)	a2D2.5 - 2P1.5
6	1974.417	50647.9	d3 - (1S)4p	b2D1.5 - u2P0.5
4	1973.272	50677.2	(1D)4s - sp(3P)	a2D1.5 - 2P1.5
1	1971.462	50723.8	(1D)4s - sp(3P)	a2D2.5 - w2F3.5
6	1971.239	50729.5	(1D)4s - sp(3P)	a2D1.5 - 2P0.5
3	1970.585	50746.4	d3 - (1S)4p	b2D1.5 - u2P1.5
0	1959.522	51032.9	(3F)4p - (3F)6s	z2D2.5 - 4F3.5
0	1957.615	51082.6	(3F)4p - (3F)6s	z2D1.5 - 4F1.5
0	1954.745	51157.6	(3F)4p - (3F)6s	z2D1.5 - 4F2.5
1	1941.986	51493.7	(3F)4p - (3F)6s	z2D2.5 - 2F3.5
0	1936.796	51631.7	(3F)4p - (3F)6s	z2F2.5 - 4F1.5
3	1932.214	51754.1	(3F)4p - (3F)6s	z2F3.5 - 2F2.5
0	1932.094	51757.3	(3F)4p - (3F)6s	z4F4.5 - 4F3.5
0	1930.486	51800.4	(3F)4p - (3F)6s	z4F3.5 - 4F2.5
0	1927.488	51881.0	d3 - sp(3P)	b4F4.5 - 4F4.5
2	1925.125	51944.7	(3F)4p - (3F)6s	z4F3.5 - 4F3.5

	1924.721	51955.6	(3F)4p - (3F)6s	z4F2.5 - 4F2.5
5	1924.704	51956.0	(3F)4p - (3F)6s	z4F4.5 - 4F4.5
1	1922.975	52002.8	(3F)4p - (3F)6s	z4F1.5 - 4F1.5
1	1922.029	52028.3	(3F)4p - (3F)6s	z2F3.5 - 2F3.5
1	1921.692	52037.5	(3F)4p - (3F)6s	z2F2.5 - 2F2.5
0	1920.205	52077.8	(3F)4p - (3F)6s	z4F1.5 - 4F2.5
0	1919.392	52099.8	(3F)4p - (3F)6s	z4F2.5 - 4F3.5
1	1917.789	52143.4	(3F)4p - (3F)6s	z4F3.5 - 4F4.5
6	1914.380	52236.2	(3F)4s - sp(3P)	a4F2.5 - 4F1.5
8	1914.008	52246.4	(3F)4s - sp(3P)	a4F3.5 - 4F2.5
	1911.618	52311.7	(3F)4s - sp(3P)	a4F4.5 - 4F3.5
9	1911.617	52311.7	(3F)4p - (3F)6s	z2F2.5 - 2F3.5
7	1910.938	52330.3	(3F)4s - sp(3P)	a4F1.5 - 4F1.5
7	1910.609	52339.3	(3F)4s - sp(3P)	a4F1.5 - 4D0.5
9	1909.664	52365.2	(3F)4s - sp(3P)	a4F2.5 - 4D1.5
9	1909.198	52378.0	(3F)4s - sp(3P)	a4F2.5 - 4F2.5
10	1908.205	52405.3	(3F)4s - sp(3P)	a4F3.5 - 4D2.5
7	1906.461	52453.2	(3F)4s - sp(3P)	a4F4.5 - 4D3.5
1	1906.238	52459.3	(3F)4s - sp(3P)	a4F1.5 - 4D1.5
4	1905.774	52472.1	(3F)4s - sp(3P)	a4F1.5 - 4F2.5
9	1905.509	52479.4	(3F)4s - sp(3P)	a4F3.5 - 4F3.5
1	1903.424	52536.9	(3F)4s - sp(3P)	a4F2.5 - 4D2.5
5	1900.741	52611.1	(3F)4s - sp(3P)	a4F2.5 - 4F3.5
5	1900.385	52620.9	(3F)4s - sp(3P)	a4F3.5 - 4D3.5
3	1900.021	52631.0	(3F)4s - sp(3P)	a4F1.5 - 4D2.5
	1897.447	52702.4	(3P)4s - sp(3P)	b2P1.5 - v2D1.5
12	1897.411	52703.4	(3F)4s - sp(3P)	a4F4.5 - 4F4.5
5	1895.643	52752.6	(3F)4s - sp(3P)	a4F2.5 - 4D3.5
1	1893.521	52811.7	(3P)4s - sp(3P)	b2P0.5 - v2D1.5
6	1891.393	52871.1	(3F)4s - sp(3P)	a4F3.5 - 4F4.5
2	1886.881	52997.5	(3P)4s - sp(3P)	b2P1.5 - v2D2.5
2	1886.217	53016.2	(3F)4p - (3F)6s	z4G5.5 - 4F4.5
1	1883.593	53090.0	(3F)4p - (3F)6s	z4G4.5 - 4F3.5
1	1880.422	53179.6	(3F)4p - (3F)6s	z4G3.5 - 4F2.5
1	1876.569	53288.7	(3F)4p - (3F)6s	z4G4.5 - 4F4.5
2	1876.359	53294.7	(3F)4p - (3F)6s	z4G2.5 - 4F1.5
2	1876.149	53300.7	d3 - (1S)4p	a2P1.5 - u2P0.5
0	1875.335	53323.8	(3F)4p - (3F)6s	z4G3.5 - 4F3.5
2	1875.151	53329.0	(3F)4s - sp(3P)	a4F3.5 - w2D2.5
7	1872.689	53399.2	d3 - (1S)4p	a2P1.5 - u2P1.5
3	1871.758	53425.7	d3 - (1S)4p	a2P0.5 - u2P0.5
3	1870.534	53460.7	(3F)4s - sp(3P)	a4F2.5 - w2D2.5
0	1869.054	53503.0	(3F)4s - sp(3P)	a4F2.5 - w2D1.5
3	1868.314	53524.2	d3 - (1S)4p	a2P0.5 - u2P1.5
0	1867.248	53554.8	(3F)4s - sp(3P)	a4F1.5 - w2D2.5
3	1865.772	53597.1	(3F)4s - sp(3P)	a4F1.5 - w2D1.5
1	1837.391	54425.0	(3F)4s - sp(3P)	a2F3.5 - w2F2.5
3	1835.495	54481.2	(3F)4p - (3F)5d	z4G5.5 - 4H6.5
2	1833.873	54544.3	(3F)4p - (3F)5d	z4G4.5 - 4G4.5
2	1832.638	54566.2	(1D)4s - (1S)4p	a2D1.5 - u2P0.5
5	1832.496	54570.4	(3F)4s - sp(3P)	a2F3.5 - w2F3.5
3	1831.515	54599.6	(3F)4p - (3F)5d	z4G3.5 - 4H4.5
4	1830.786	54621.3	(3F)4p - (3F)5d	z4G2.5 - 4H3.5
3	1830.468	54630.8	(1D)4s - (1S)4p	a2D2.5 - u2P1.5
2	1830.323	54635.2	(3F)4p - (3F)5d	z4G3.5 - 4G3.5
2	1829.336	54664.6	(1D)4s - (1S)4p	a2D1.5 - u2P1.5

7	1828.352	54694.1	(3F)4s - sp(3P)	a2F2.5 - w2F2.5
1	1823.505	54839.4	(3F)4s - sp(3P)	a2F2.5 - w2F3.5
4	1806.949	55341.9	(1G)4s - sp(3P)	b2G3.5 - v2F2.5
0	1797.683	55627.2	(1G)4s - sp(3P)	b2G3.5 - v2F3.5
1	1797.418	55635.4	(1G)4s - sp(3P)	b2G4.5 - v2F3.5
0	1767.740	56569.4	d3 - sp(3P)	b2D2.5 - v2D1.5
0	1763.706	56698.8	d3 - sp(3P)	b2D1.5 - v2D1.5
0	1758.566	56864.5	d3 - sp(3P)	b2D2.5 - v2D2.5
1	1754.303	57002.7	(3P)4s - sp(3P)	b2P1.5 - 2P0.5
4	1750.962	57111.5	s2 - (3F)4f	c2D2.5 - 4S1.5
4	1744.443	57324.9	(3P)4s - sp(3P)	b2P1.5 - 2P1.5
1	1741.124	57434.2	(3P)4s - sp(3P)	b2P0.5 - 2P1.5
0	1731.495	57753.6	(3P)4s - (3F)5p	b2P1.5 - 2D1.5
1	1728.225	57862.8	(3P)4s - (3F)5p	b2P0.5 - 2D1.5
1	1724.768	57978.8	d3 - sp(3P)	b2D1.5 - v2F2.5
2	1723.544	58020.0	(3P)4s - (3F)5p	b2P1.5 - 2D2.5
2	1720.144	58134.7	d3 - sp(3P)	b2D2.5 - v2F3.5
4	1716.554	58256.3	(1G)4s - (3F)5p	b2G3.5 - 2F2.5
0	1708.378	58535.0	(1G)4s - (3F)5p	b2G3.5 - 2F3.5
4	1708.139	58543.2	(1G)4s - (3F)5p	b2G4.5 - 2F3.5
0	1681.333	59476.6	d3 - sp(3P)	a2P0.5 - v2D1.5
0	1676.538	59646.7	d3 - sp(3P)	a2P1.5 - v2D2.5
1	1660.934	60207.1	d3 - (3F)5p	a2H4.5 - 2G3.5
1	1656.763	60358.7	d3 - (3F)5p	a2H5.5 - 2G4.5
0	1650.621	60583.3	(1D)4s - sp(3P)	a2D2.5 - v2D1.5
3	1649.700	60617.1	(1D)4s - sp(3P)	a2D1.5 - v2D1.5
0	1646.519	60734.2	d3 - (3F)4f	b2F2.5 - 2G3.5
0	1644.132	60822.4	d3 - (3F)4f	b2F2.5 - 4F2.5
3	1642.619	60878.4	(1D)4s - sp(3P)	a2D2.5 - v2D2.5
	1641.788	60909.2	d3 - (3F)4f	b2F2.5 - 4G3.5
0	1641.708	60912.2	(1D)4s - sp(3P)	a2D1.5 - v2D2.5
0	1640.678	60950.4	d3 - (3F)4f	b2F3.5 - 2G4.5
0	1639.569	60991.6	d3 - (3F)4f	b2F2.5 - 2F2.5
1	1639.369	60999.1	d3 - sp(3P)	b2D1.5 - 2P0.5
0	1638.773	61021.3	d3 - (3F)4f	b2F3.5 - 4F3.5
0	1638.201	61042.6	d3 - (3F)5p	b2D2.5 - 2F3.5
0	1634.340	61186.8	d3 - (3F)4f	b2F3.5 - 4G4.5
2	1634.203	61191.9	d3 - sp(3P)	b2D2.5 - 2P1.5
0	1632.396	61259.6	d3 - (3F)4f	b2F3.5 - 2F3.5
1	1629.867	61354.7	d3 - (3F)4f	b2F3.5 - 4D2.5
0	1627.942	61427.2	d3 - (3F)4f	b2F3.5 - 2D2.5
1	1623.118	61609.8	d3 - sp(3P)	a2G3.5 - v2F2.5
1	1618.790	61774.5	d3 - sp(3P)	a2G4.5 - v2F3.5
0	1571.045	63651.9	d3 - sp(3P)	a2P1.5 - 2P0.5
3	1567.965	63776.9	d3 - sp(3P)	a2P0.5 - 2P0.5
1	1563.133	63974.1	d3 - sp(3P)	a2P1.5 - 2P1.5
0	1562.132	64015.1	d3 - (3F)5p	a2G4.5 - 2G4.5
0	1549.720	64527.8	d3 - (3F)5p	a2P0.5 - 2D1.5
0	1546.332	64669.2	d3 - (3F)5p	a2P1.5 - 2D2.5
5	1545.620	64698.9	(3F)4s - sp(3P)	a2F2.5 - v2D1.5
6	1544.999	64725.0	(3F)4s - sp(3P)	a2F3.5 - v2D2.5
0	1542.938	64811.4	(1D)4s - (3F)5p	a2D1.5 - 2F2.5
1	1538.602	64994.0	(3F)4s - sp(3P)	a2F2.5 - v2D2.5
0	1537.127	65056.4	(1D)4s - (3F)5p	a2D2.5 - 2F3.5
1	1522.806	65668.2	(1D)4s - (3F)5p	a2D1.5 - 2D1.5
0	1521.841	65709.9	(3F)4s - sp(3P)	a2F3.5 - v2F2.5

1	1517.431	65900.8	(1D)4s - (3F)5p	a2D2.5 - 2D2.5
4	1515.635	65979.0	(3F)4s - sp(3P)	a2F2.5 - v2F2.5
5	1515.263	65995.1	(3F)4s - sp(3P)	a2F3.5 - v2F3.5
0	1509.110	66264.2	(3F)4s - sp(3P)	a2F2.5 - v2F3.5
2	1451.520	68893.3	(3F)4s - (3F)5p	a2F2.5 - 2F2.5
2	1451.315	68903.0	(3F)4s - (3F)5p	a2F3.5 - 2F3.5
0	1450.044	68963.4	d3 - (3F)4f	a2H5.5 - 4I4.5
0	1447.992	69061.2	d3 - (3F)4f	a2H4.5 - 4I4.5
0	1447.861	69067.4	d3 - (3F)4f	a2H5.5 - 2G4.5
1	1447.660	69077.0	d3 - (3F)4f	a2H4.5 - 4H5.5
0	1446.869	69114.8	d3 - (3F)4f	a2H5.5 - 4I5.5
	1446.238	69144.9	d3 - (3F)4f	a2H5.5 - 4I6.5
1	1446.231	69145.3	d3 - (3F)4f	b2D1.5 - 4F2.5
0	1446.031	69154.8	d3 - (3F)4f	b2D2.5 - 4F3.5
0	1445.670	69172.1	(3F)4s - (3F)5p	a2F2.5 - 2F3.5
0	1444.826	69212.5	d3 - (3F)4f	a2H4.5 - 4I5.5
0	1444.105	69247.0	d3 - (3F)4f	a2H4.5 - 2H4.5
0	1443.040	69298.1	d3 - (3F)4f	a2H5.5 - 4H6.5
0	1442.699	69314.5	d3 - (3F)4f	b2D1.5 - 2F2.5
3	1442.501	69324.0	d3 - (3F)4f	a2H4.5 - 2I5.5
0	1441.423	69375.9	d3 - (3F)4f	b2D2.5 - 4D3.5
	1441.084	69392.2	d3 - (3F)4f	b2D1.5 - 4D1.5
0	1441.063	69393.2	d3 - (3F)4f	b2D2.5 - 2F3.5
0	1440.892	69401.5	d3 - (3F)4f	a2H4.5 - 4G4.5
1	1440.743	69408.6	d3 - (3F)4f	a2H5.5 - 2H5.5
0	1440.381	69426.1	d3 - (3F)4f	a2H4.5 - 4G5.5
0	1440.160	69436.7	d3 - (3F)4f	b2D1.5 - 2D1.5
4	1438.652	69509.5	d3 - (3F)4f	a2H5.5 - 2I6.5
1	1437.591	69560.8	d3 - (3F)4f	b2D2.5 - 2D2.5
0	1435.195	69676.9	d3 - sp(3P)	b4F4.5 - v2F3.5
	1433.744	69747.4	(3F)4s - (3F)5p	a2F3.5 - 2D2.5
5	1433.690	69750.1	(3F)4s - (3F)5p	a2F2.5 - 2D1.5
0	1428.235	70016.5	(3F)4s - (3F)5p	a2F2.5 - 2D2.5
0	1415.225	70660.1	d3 - (3F)5p	b4F3.5 - 4G4.5
0	1413.826	70730.1	d3 - (3F)5p	b4F4.5 - 4G5.5
0	1413.658	70738.5	d3 - (3F)5p	b4F3.5 - 4F2.5
	1413.538	70744.4	d3 - (3F)5p	b4F4.5 - 4F3.5
0	1413.533	70744.7	d3 - (3F)5p	b4F2.5 - 4F1.5
0	1412.018	70820.6	d3 - (3F)5p	b4F1.5 - 4F1.5
1	1411.594	70841.9	d3 - (3F)5p	b4F2.5 - 4F2.5
1	1410.975	70873.0	d3 - (3F)5p	b4F3.5 - 4F3.5
2	1410.221	70910.9	d3 - (3F)5p	b4F4.5 - 4F4.5
0	1410.083	70917.8	d3 - (3F)5p	b4F1.5 - 4F2.5
0	1408.919	70976.4	d3 - (3F)5p	b4F2.5 - 4F3.5
0	1407.670	71039.4	d3 - (3F)5p	b4F3.5 - 4F4.5
1	1401.461	71354.1	d3 - (3F)5p	b4F2.5 - 4D1.5
	1401.300	71362.3	d3 - (3F)5p	b4F1.5 - 4D0.5
2	1401.263	71364.2	d3 - (3F)5p	b4F3.5 - 4D2.5
2	1400.697	71393.0	d3 - (3F)5p	b4F4.5 - 4D3.5
0	1399.973	71430.0	d3 - (3F)5p	b4F1.5 - 4D1.5
0	1399.353	71461.6	(3F)4s - (3F)5p	a4F1.5 - 4G2.5
0	1399.235	71467.6	d3 - (3F)5p	b4F2.5 - 4D2.5
0	1398.759	71492.0	(3F)4s - (3F)5p	a4F2.5 - 4G3.5
	1398.180	71521.5	d3 - (3F)5p	b4F3.5 - 4D3.5
1	1398.176	71521.7	(3F)4s - (3F)5p	a4F3.5 - 4G4.5
1	1397.576	71552.5	(3F)4s - (3F)5p	a4F4.5 - 4G5.5

0	1387.163	72089.6	d3 - (3F)4f	a2P1.5 -	2D1.5
0	1385.660	72167.8	d3 - (3F)4f	a4P2.5 -	2G3.5
1	1384.762	72214.6	d3 - (3F)4f	a2P0.5 -	2D1.5
0	1383.694	72270.3	d3 - (3F)4f	a2P1.5 -	4D2.5
1	1382.584	72328.3	d3 - (3F)4f	a2P1.5 -	4S1.5
1	1382.581	72328.5	d3 - (3F)4f	a4P1.5 -	4G2.5
0	1381.630	72378.3	d3 - (3F)4f	a4P1.5 -	4F2.5
1	1381.313	72394.9	d3 - (3F)4f	a4P2.5 -	4F3.5
1	1380.735	72425.2	d3 - (3F)4f	a4P2.5 -	2F2.5
1	1379.233	72504.1	d3 - (3F)4f	a4P0.5 -	4P1.5
0	1378.948	72519.1	d3 - (3F)4f	a2P0.5 -	2P1.5
0	1378.406	72547.5	d3 - (3F)4f	a4P1.5 -	2F2.5
1	1377.389	72601.1	d3 - (3F)4f	a4P1.5 -	4P2.5
0	1377.108	72615.9	d3 - (3F)4f	a4P2.5 -	4D3.5
0	1376.733	72635.7	d3 - (3F)4f	a2G4.5 -	4H5.5
0	1375.890	72680.2	d3 - (3F)4f	a4P0.5 -	4P0.5
1	1375.741	72688.1	d3 - (3F)4f	a2G3.5 -	2G3.5
1	1375.065	72723.8	d3 - (3F)4f	a2G4.5 -	2G4.5
0	1374.980	72728.3	d3 - (3F)4f	a4P2.5 -	4D2.5
1	1374.751	72740.4	d3 - (3F)4f	a2G3.5 -	4I4.5
0	1374.170	72771.2	d3 - (3F)4f	a2G4.5 -	4I5.5
0	1372.790	72844.4	d3 - (3F)4f	a2G3.5 -	2G4.5
1	1372.648	72851.9	d3 - (3F)4f	a4P2.5 -	2P1.5
0	1372.436	72863.1	d3 - (3F)4f	a2G3.5 -	4G3.5
1	1372.055	72883.4	(1D)4s - (3F)4f	a2D2.5 -	4H3.5
0	1371.599	72907.6	(3F)4s - (3F)5p	a4F3.5 -	2G4.5
2	1371.248	72926.3	d3 - (3F)4f	a2G3.5 -	2H4.5
0	1370.978	72940.6	d3 - (3F)4f	a4P0.5 -	4S1.5
0	1370.886	72945.5	d3 - (3F)4f	a2G3.5 -	2F2.5
2	1370.611	72960.2	d3 - (3F)4f	a2G4.5 -	4G4.5
0	1369.568	73015.7	d3 - (3F)4f	a2G4.5 -	4D3.5
0	1369.243	73033.1	d3 - (3F)4f	a2G4.5 -	2F3.5
3	1368.643	73065.1	d3 - (3F)4f	a2G4.5 -	2H5.5
1	1368.350	73080.7	d3 - (3F)4f	a2G3.5 -	4G4.5
0	1366.987	73153.6	d3 - (3F)4f	a2G3.5 -	2F3.5
1	1241.648	80538.1	d3 - (3F)4f	b4F4.5 -	4H5.5
2	1240.864	80589.0	d3 - (3F)4f	b4F3.5 -	4H4.5
0	1240.718	80598.5	d3 - (3F)4f	b4F3.5 -	2G3.5
0	1240.291	80626.2	d3 - (3F)4f	b4F4.5 -	2G4.5
0	1240.022	80643.8	d3 - (3F)4f	b4F2.5 -	4H3.5
0	1239.913	80650.8	d3 - (3F)4f	b4F3.5 -	4I4.5
1	1239.562	80673.6	d3 - (3F)4f	b4F4.5 -	4I5.5
2	1239.128	80701.9	d3 - (3F)4f	b4F2.5 -	2G3.5
0	1239.032	80708.1	d3 - (3F)4f	b4F4.5 -	2H4.5
0	1238.317	80754.8	d3 - (3F)4f	b4F3.5 -	2G4.5
0	1238.029	80773.5	d3 - (3F)4f	b4F3.5 -	4G3.5
1	1237.775	80790.1	d3 - (3F)4f	b4F2.5 -	4F2.5
2	1237.376	80816.2	d3 - (3F)4f	b4F1.5 -	4G2.5
1	1237.232	80825.6	d3 - (3F)4f	b4F3.5 -	4F3.5
2	1237.062	80836.7	d3 - (3F)4f	b4F3.5 -	2H4.5
0	1236.768	80855.9	d3 - (3F)4f	b4F3.5 -	2F2.5
1	1236.666	80862.6	d3 - (3F)4f	b4F4.5 -	4G4.5
3	1236.446	80877.0	d3 - (3F)4f	b4F2.5 -	4G3.5
4	1236.289	80887.2	d3 - (3F)4f	b4F4.5 -	4G5.5
0	1235.817	80918.2	d3 - (3F)4f	b4F4.5 -	4D3.5
4	1235.610	80931.7	d3 - (3F)4f	b4F4.5 -	4F4.5

1	1235.183	80959.7	d3 - (3F)4f	b4F1.5 - 4P1.5
1	1235.064	80967.5	d3 - (3F)4f	b4F4.5 - 2H5.5
4	1234.703	80991.1	d3 - (3F)4f	b4F3.5 - 4G4.5
2	1234.371	81012.9	d3 - (3F)4f	b4F2.5 - 4P2.5
0	1234.003	81037.1	d3 - (3F)4f	b4F2.5 - 4D1.5
1	1233.857	81046.7	d3 - (3F)4f	b4F3.5 - 4D3.5
2	1233.593	81064.0	d3 - (3F)4f	b4F3.5 - 2F3.5
0	1233.326	81081.6	d3 - (3F)4f	b4F2.5 - 2D1.5
0	1233.216	81088.8	d3 - (3F)4f	b4F1.5 - 4P2.5
2	1233.038	81100.5	d3 - (3F)4f	b4F1.5 - 4D0.5
1	1232.501	81135.8	d3 - (3F)4f	b4F1.5 - 4P0.5
0	1232.021	81167.4	d3 - (3F)4f	b4F2.5 - 2F3.5
0	1229.483	81335.0	d3 - (3F)4f	b4F2.5 - 2D2.5

Table III. Even levels of Ti II

Config.	Term	J	Level (cm^{-1})	Eigenvector components [a] First	Second and third			
$3d^2(^3F)4s$	a^4F	1.5	0.00	100				
		2.5	94.10	100				
		3.5	225.73	100				
		4.5	393.44	100				
$3d^3$	b^4F	1.5	908.02	100				
		2.5	983.89	100				
		3.5	1087.32	100				
		4.5	1215.84	100				
$3d^2(^3F)4s$	a^2F	2.5	4628.58	99				
		3.5	4897.65	99				
$3d^2(^1D)4s$	a^2D	1.5	8710.44	73	16	b^2D2		
		2.5	8744.25	76	15	b^2D2		
$3d^3$	a^2G	3.5	8997.71	96				
		4.5	9118.26	96				
$3d^3$	a^4P	0.5	9353.62	89	10	a^2P		
		1.5	9395.71	85	11	a^2P		
		2.5	9518.06	100				
$3d^3$	a^2P	0.5	9850.90	66	23	b^2P	11	a^4P
		1.5	9975.92	57	20	b^2P	14	a^4P
$3d^2(^3P)4s$	b^4P	0.5	9872.73	99				
		1.5	9930.69	92				
		2.5	10024.73	99				
$3d^3$	b^2D2	1.5	12628.73	53	24	a^2D	21	d^2D1
		2.5	12758.11	55	23	a^2D	21	d^2D1
$3d^3$	a^2H	4.5	12676.97	100				
		5.5	12774.69	100				
$3d^2(^1G)4s$	b^2G	3.5	15265.62	96				
		4.5	15257.43	96				

$3d^2(^3P)4s$	b^2P	0.5	16515.86	75	25	a^2P		
		1.5	16625.11	75	25	a^2P		
$3d^3$	b^2F	2.5	20951.62	99				
		3.5	20891.66	99				
$3d4s^2$	c^2D	1.5	24961.03	74	13	b^2D1	13	d^2D2
		2.5	25192.79	72	15	d^2D1	13	b^2D2
$3d^2(^1S)4s$	a^2S	0.5	31787.75	100				
$3d^3$	d^2D1	1.5	32275.32	58	24	c^2D	17	b^2D2
		2.5	32332.73	58	26	c^2D	16	b^2D2
$3d^2(^3F)5s$	e^4F	1.5	62180.16					
		2.5	62272.16					
		3.5	62410.78					
		4.5	62595.03					
$3d^2(^3F)5s$	e^2F	2.5	63169.02					
		3.5	63445.88					
$3d^2(^3F)4d$	e^4G	2.5	64886.48					
		3.5	64979.15					
		4.5	65095.80					
		5.5	65243.46					
$3d^2(^3F)4d$	e^4H	3.5	65186.75					
		4.5	65308.30					
		5.5	65446.27					
		6.5	65590.19					
$3d^2(^3F)4d$	^4D	0.5	65213.80					
		1.5	65274.60					
		2.5	65397.57					
		3.5	65598.73					
$3d^2(^3F)4d$	f^2F	2.5	65314.27					
		3.5	65460.01					
$3d^2(^3F)4d$	^2P	0.5	66521.01					
		1.5	66794.01					

$3d^2(^3F)4d$	e^2G	3.5	67606.04
		4.5	67822.49
$3d^2(^3F)4d$	e^2H	4.5	68331.02
		5.5	68584.28
$3d^2(^3F)4d$	^2D	1.5	68364.39
		2.5	68482.41
$3d^2(^3F)4d$	f^4F	1.5	68769.19
		2.5	68846.52
		3.5	68951.98
		4.5	69084.44
$3d^2(^3F)6s$	^4F	1.5	82839.08
		2.5	82914.09
		3.5	83058.33
		4.5	83257.04
$3d^2(^3F)6s$	^2F	2.5	83244.91
		3.5	83519.16
$3d^2(^3F)5d$	^4H	3.5	84165.71
		4.5	84334.14
		5.5	84490.76
		6.5	84722.08
$3d^2(^3F)5d$	^4G	2.5	84268.77
		3.5	84369.70
		4.5	84512.57
		5.5	84632.03

a) LS eigenvector components for $(3d + 4s)^3$. Components smaller than 10% have been omitted.

a) [illegible] for (34 [illegible] (components smaller than 10%
[illegible]

Table IV. Odd levels of Ti II

Config.	Term	J	Level (cm^{-1})	Eigenvector components [a] First	Second
$3d^2(^3F)4p$	z^4G	2.5	29544.37	98	
		3.5	29734.54	99	
		4.5	29968.30	99	
		5.5	30240.88	99	
$3d^2(^3F)4p$	z^4F	1.5	30836.32	96	
		2.5	30958.50	98	
		3.5	31113.65	98	
		4.5	31301.01	99	
$3d^2(^3F)4p$	z^2F	2.5	31207.42	84	
		3.5	31490.82	87	
$3d^2(^3F)4p$	z^2D	1.5	31756.51	82	
		2.5	32025.47	78	
$3d^2(^3F)4p$	z^4D	0.5	32532.21	97	
		1.5	32602.55	94	
		2.5	32697.99	91	
		3.5	32767.07	95	
$3d^2(^3F)4p$	z^2G	3.5	34543.26	94	
		4.5	34748.40	94	
$3d^2(^3P)4p$	z^2S	0.5	37430.58	99	
$3d^2(^1D)4p$	y^2D	1.5	39602.75	48	36 z^2P
		2.5	39476.80	64	15 y^2F
$3d^2(^1D)4p$	z^2P	0.5	39674.66	97	
		1.5	39233.28	58	32 y^2D
$3d^2(^1D)4p$	y^2F	2.5	39926.66	72	15 y^2D
		3.5	40074.52	84	
$3d^2(^3P)4p$	z^4S	1.5	40027.11	96	

$3d^2(^3P)4p$	y^4D	0.5	40330.16	97
		1.5	40425.59	96
		2.5	40581.49	95
		3.5	40798.30	92
$3d^2(^3P)4p$	z^4P	0.5	41996.57	97
		1.5	42068.52	97
		2.5	42208.59	97
$3d^2(^1G)4p$	y^2G	3.5	43740.65	94
		4.5	43780.79	94
$3d^2(^3P)4p$	x^2D	1.5	44914.70	79
		2.5	44902.29	81
$3d^2(^3P)4p$	y^2P	0.5	45472.27	94
		1.5	45548.76	92
$3d^2(^1G)4p$	z^2H	4.5	45673.62	99
		5.5	45908.53	99
$3d^2(^1G)4p$	x^2F	2.5	47624.88	91
		3.5	47466.54	91
$3d(^2D)4s4p(^3P)$	^4F	1.5	52330.33	
		2.5	52472.12	
		3.5	52705.16	
		4.5	53096.83	
$3d(^2D)4s4p(^3P)$	^4D	0.5	52339.34	
		1.5	52459.33	
		2.5	52631.00	
		3.5	52846.65	
$3d(^2D)4s4p(^3P)$	w^2D	1.5	53597.10	
		2.5	53554.76	
$3d(^2D)4s4p(^3P)$	y^4P	0.5	56222.81	
		1.5	56249.10	
		2.5	56325.70	
$3d(^2D)4s4p(^3P)$	w^2F	2.5	59322.65	
		3.5	59468.02	

$3d(^2D)4s4p(^3P)$	^2P	0.5	59439.94			
		1.5	59387.68			
$3d^2(^1S)4p$	^2P	0.5	63276.60	77	19	$(^3P)^2P$
		1.5	63375.08	81	16	$(^3P)^2P$
$3d(^2D)4s4p(^1P)$	v^2D	1.5	69327.52			
		2.5	69622.63			
$3d(^2D)4s4p(^1P)$	v^2F	2.5	70607.53			
		3.5	70892.79			
$3d^2(^3F)5p$	^4F	1.5	71728.62			
		2.5	71825.81			
		3.5	71960.29			
		4.5	72126.70			
$3d^2(^3F)5p$	^4G	2.5	71461.59			
		3.5	71586.06			
		4.5	71747.46			
		5.5	71945.90			
$3d^2(^3F)5p$	^4D	0.5	72270.31			
		1.5	72337.97			
		2.5	72451.52			
		3.5	72608.85			
$3d^2(^3F)5p$	^2G	3.5	72884.04			
		4.5	73133.35			
$3d^2(^3F)5p$	^2F	2.5	73521.87			
		3.5	73800.67			
$3d(^2D)4s4p(^1P)$	^2P	0.5	73627.82			
		1.5	73950.01			
$3d(^3F)5p$	^2D	1.5	74378.67			
		2.5	74645.08			
$3d^2(^3F)4f$	^4H	3.5	81627.64			
		4.5	81676.30			
		5.5	81753.98			
		6.5	82072.84			

$3d^2(^3F)4f$	^2G	3.5	81685.81
		4.5	81842.09
$3d^2(^3F)4f$	^4G	2.5	81724.17
		3.5	81860.84
		4.5	82078.43
		5.5	82103.06
$3d^2(^3F)4f$	^4I	4.5	81738.13
		5.5	81889.46
		6.5	81919.58
		7.5	82216.91
$3d^2(^3F)4f$	^4F	1.5	81806.88
		2.5	81773.98
		3.5	81912.92
		4.5	82147.54
$3d^2(^3F)4f$	^4P	0.5	82043.85
		1.5	81867.70
		2.5	81996.83
$3d^2(^3F)4f$	^2H	4.5	81923.99
		5.5	82183.31
$3d^2(^3F)4f$	^2F	2.5	81943.25
		3.5	82151.31
$3d^2(^3F)4f$	^4D	0.5	82008.55
		1.5	82020.94
		2.5	82246.37
		3.5	82133.99
$3d^2(^3F)4f$	^2P	0.5	
		1.5	82369.97
$3d^2(^3F)4f$	^2I	5.5	82001.01
		6.5	82284.22
$3d^2(^3F)4f$	^2D	1.5	82065.47
		2.5	82318.91
$3d^2(^3F)4f$	^4S	1.5	82304.25

a) LS eigenvector components for $3d^2 4p$. Components smaller than 10% have been omitted.